



Ranger to Artemis A History of Lunar Exploration Tools DIY Lunar Experiments

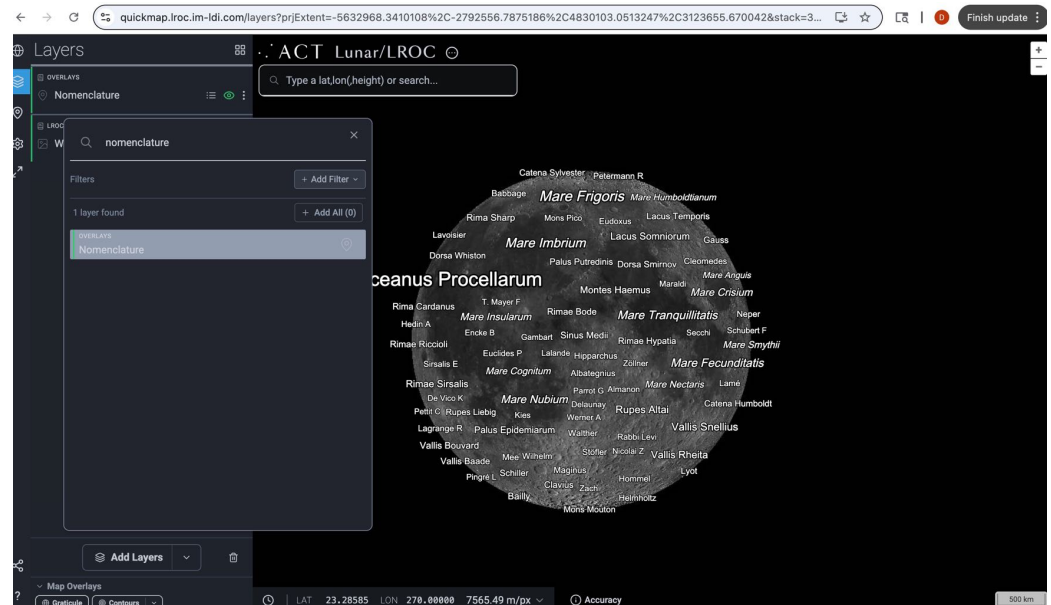
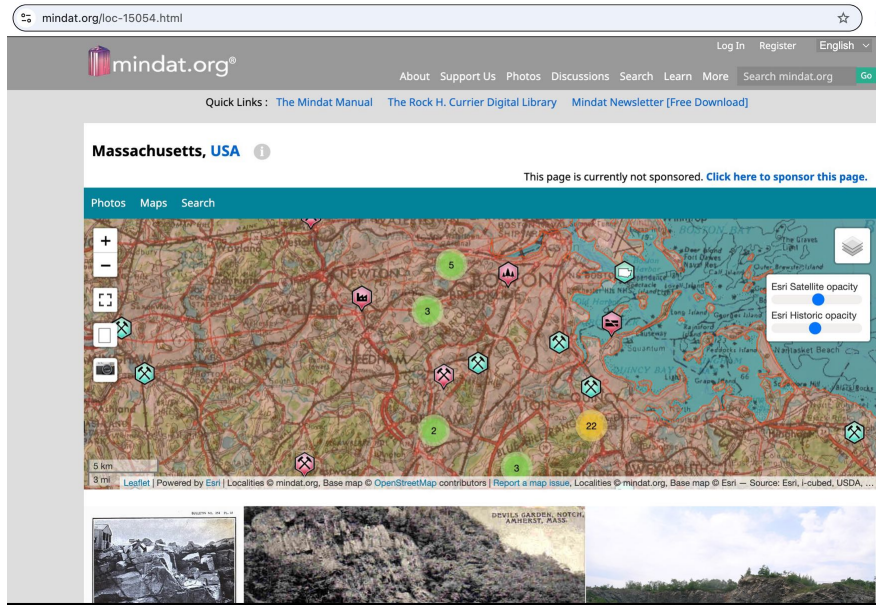
Erik Hunter, PhD
ehunter@kessingerhunter.com



Pembroke Country Day School - 1976



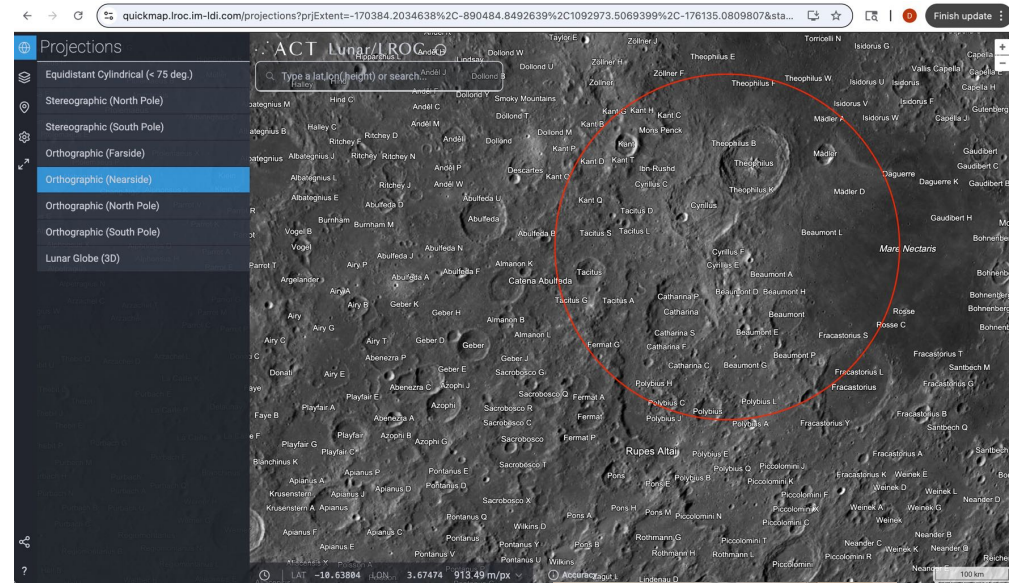
Step One: Mapping



<https://quickmap.lroc.im-ldi.com/>



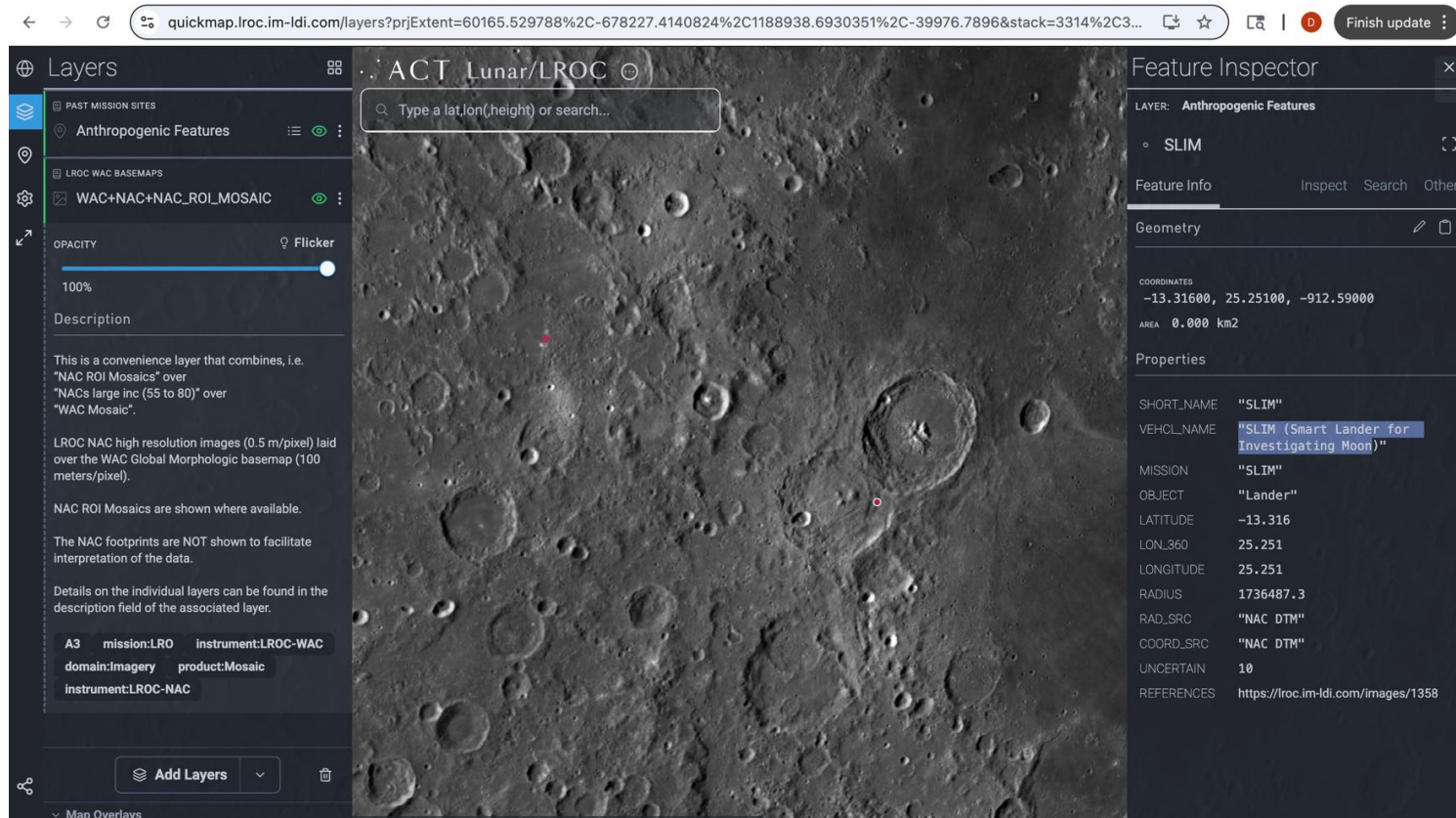
iPhone Photo (May 2025)



Cyrillus is a [lunar impact crater](#) located on the northwest edge of [Mare Nectaris](#). Intruding into the northeast rim is the slightly larger, and younger crater [Theophilus](#). To the south is another prominent crater named [Catharina](#). Together these three craters form a prominent trio in the southeast quadrant of the [Moon](#).

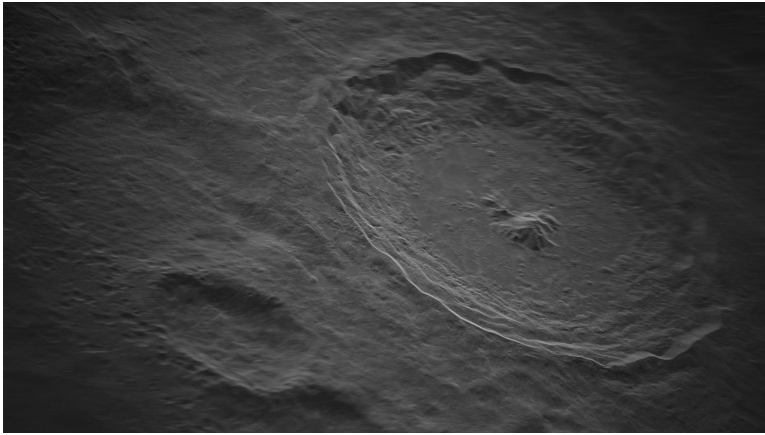


Jason Model 307 (Late 70's)



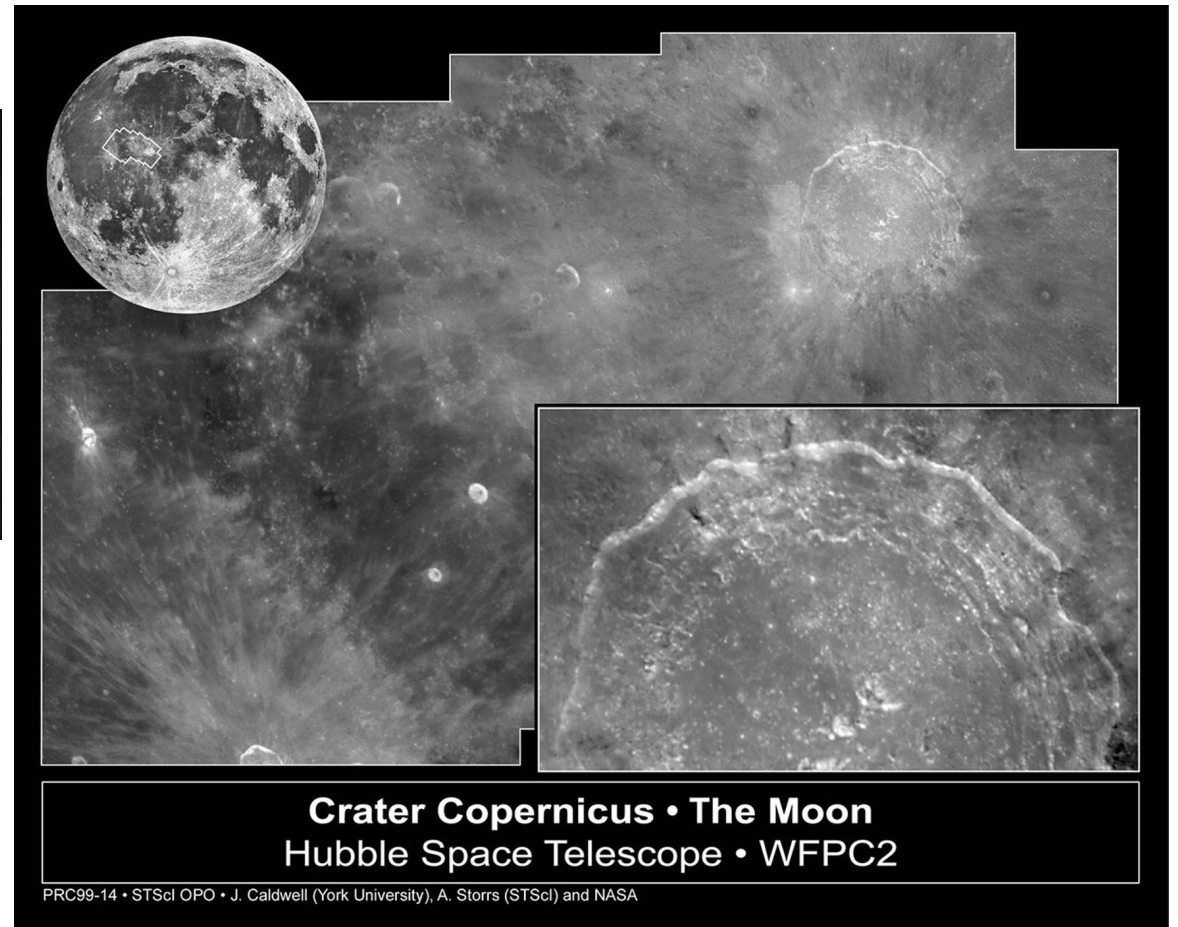
The Smart Lander for Investigating Moon (SLIM), nicknamed the "Moon Sniper", was a lunar lander mission operated by the Japan Aerospace Exploration Agency (JAXA). SLIM entered lunar orbit on December 25, 2023, and successfully soft-landed on the Moon on January 19, 2024. During its descent, the lander recognized lunar craters by applying technology from facial recognition systems,

Limitations of Telescopes



The moon's Tycho Crater in 16-foot (5-meter) resolution detail, as imaged by a prototype radar system at the Green Bank Telescope. (Image credit: NRAO/GBO/Raytheon/NSF/AUI)

<https://www.space.com/green-bank-radar-highest-resolution-moon-photos>



Crater Copernicus • The Moon
Hubble Space Telescope • WFPC2

PRC99-14 • STScI OPO • J. Caldwell (York University), A. Storrs (STScI) and NASA

Hubble can resolve features as small as 280 feet across.
Apollo Lander is 23 feet in diameter.

Apollo 11 Lunar Descent Stage



India's Chandrayaan-2 orbiter, using its Orbiter High Resolution Camera (OHRC), captured high-resolution images of the Apollo 11 landing site at Tranquility Base from 100 km above the Moon.

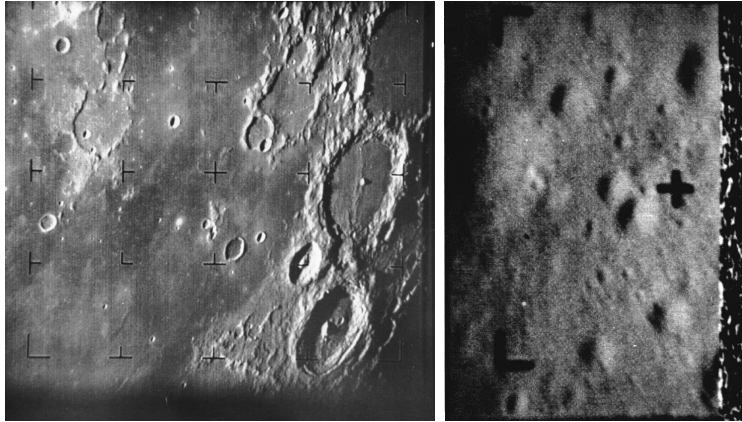
- [Luna program](#) — USSR Lunar exploration (1959–1976)
- [Ranger program](#) — US Lunar hard-landing probes (1961–1965)
- [Zond program](#) — USSR Lunar exploration (1964–1970)
- [Surveyor program](#) — US Lunar soft-landing probe (1966–1968)
- [Lunar Orbiter program](#) — US Lunar orbital (1966–1967)
- [Lunokhod program](#) — USSR [Lunar Rover](#) probes (1970–1973)
- [Chang'e program](#) - China Lunar [orbiters](#), [landers](#), [rovers](#) and [sample return spacecrafts](#) (2004–present)
- [Chandrayaan programme](#) - Indian Lunar Exploration Programme incorporates lunar [orbiters](#), [impactors](#), [soft landers](#) and [rover spacecrafts](#) (2008–present)

Japanese Moon Probes (JAXA & Private)

- **SLIM (Smart Lander for Investigating Moon):** JAXA probe that successfully achieved a precision landing on Jan 19, 2024.
- **Hakuto-R Mission 1 (ispace):** Private lander that failed in its 2023 landing attempt.
- **Resilience (Hakuto-R Mission 2 / ispace):** Launched Jan 15, 2025, for a planned May/June 2025 landing on the far north.
- **Yaoki (Dymon Corp):** A tiny Japanese micro-rover (498 grams) launched with the Intuitive Machines IM-2 mission in 2025.
- **EQUULEUS:** JAXA probe launched in 2022 to study Earth's plasmasphere and map lunar dust.
- **LUPEX (Lunar Polar Exploration):** Future joint JAXA/India mission.

Intuitive Machines Lunar Probes (USA)

- **IM-1 (Odysseus):** Landed on Feb 22, 2024, at Malapert A, becoming the first commercial spacecraft to land on the Moon.
- **IM-2 (Athena):** Launched Feb 26, 2025, to the South Pole (Mons Mouton). It reached the surface in March 2025 but landed on its side and failed to operate, carrying a Micro Hopper (Grace) and a Japanese rover.
- **IM-3:** Scheduled for late 2026, targeting the Reiner Gamma site.
- **IM-4:** Planned for 2027 to the lunar south pole.

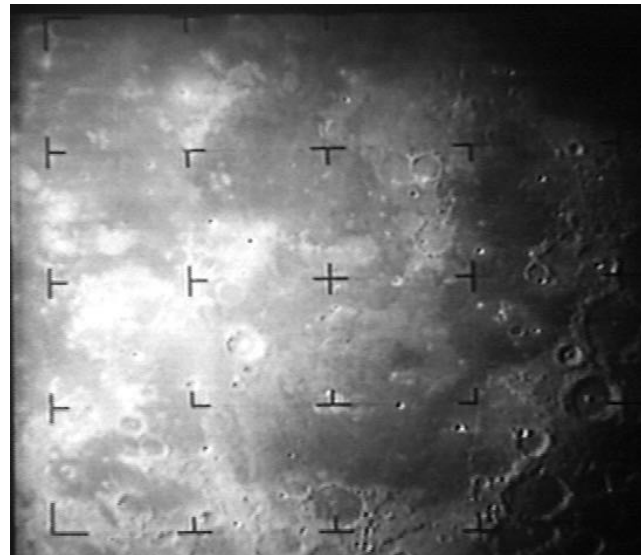
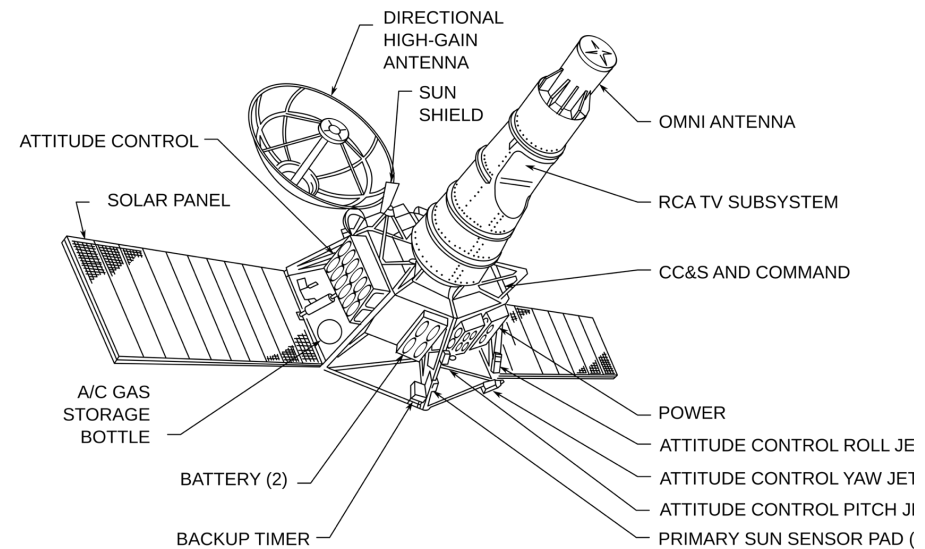


Left: The first image returned by Ranger 7.

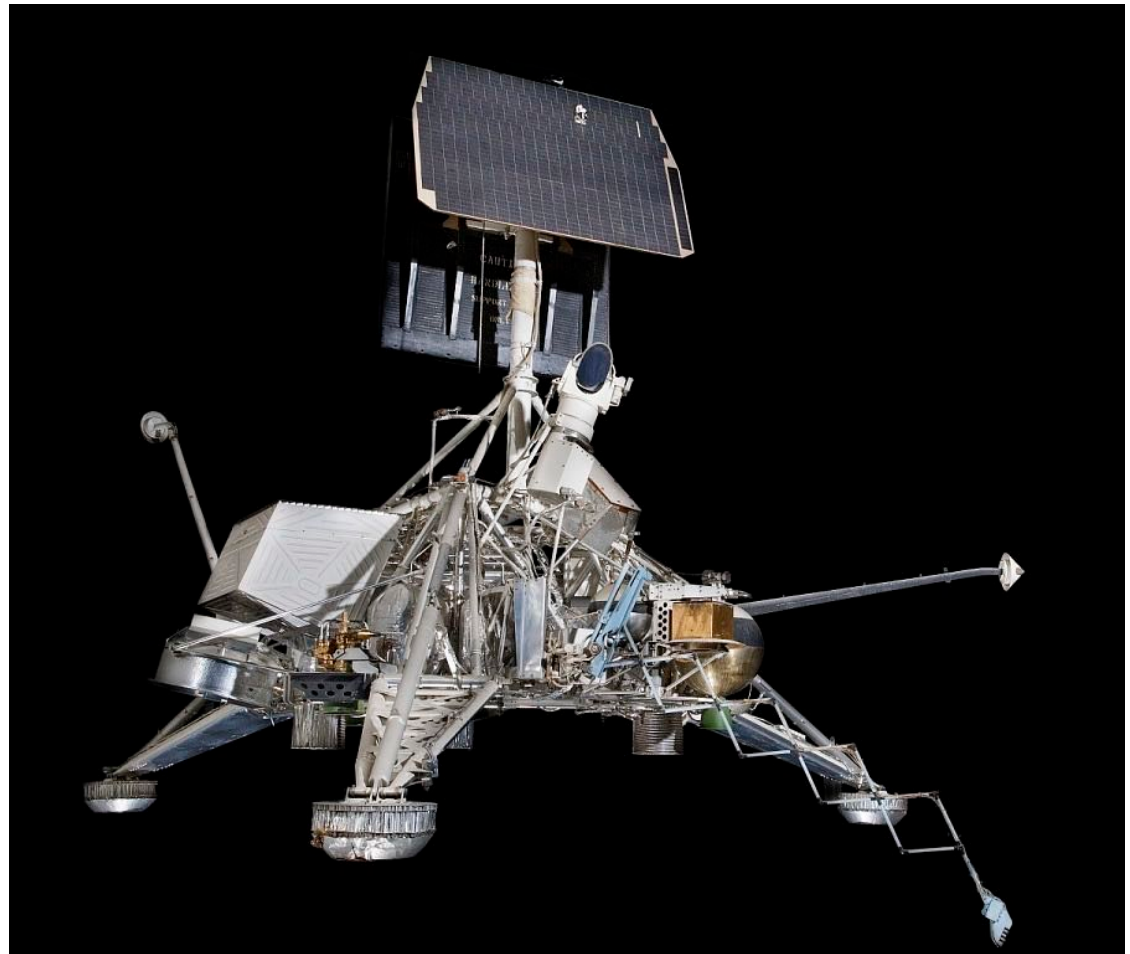
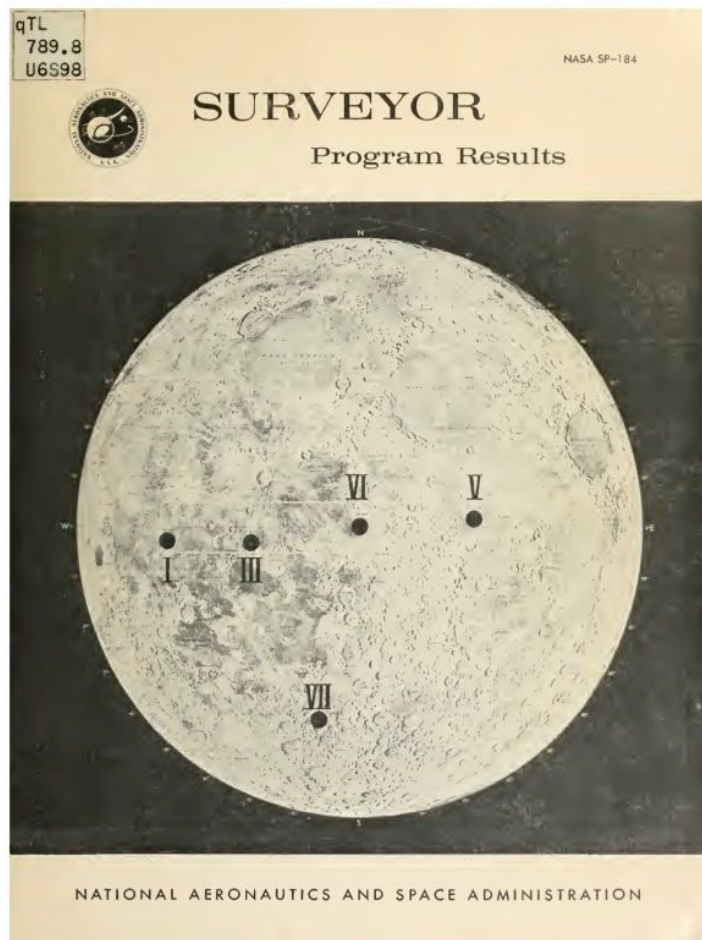
Right: The final image returned by Ranger 7.

(First 6 missions failed) On July 31, 1964 Ranger 7 reached the Moon. During its final 17 minutes of flight, the spacecraft sent back [4,316 images](#) of the lunar surface. The last image taken 2.3 seconds before impact had a resolution of just half-a-meter. The area in which it crashed – between *Mare Nubium* and *Oceanus Procellarum* – was renamed *Mare Cognitum*, Latin for “The Sea that has Become Known,” in honor of being the first spot on the Moon seen close-up.

<https://www.nasa.gov/history/55-years-ago-ranger-7-photographs-the-moon/>

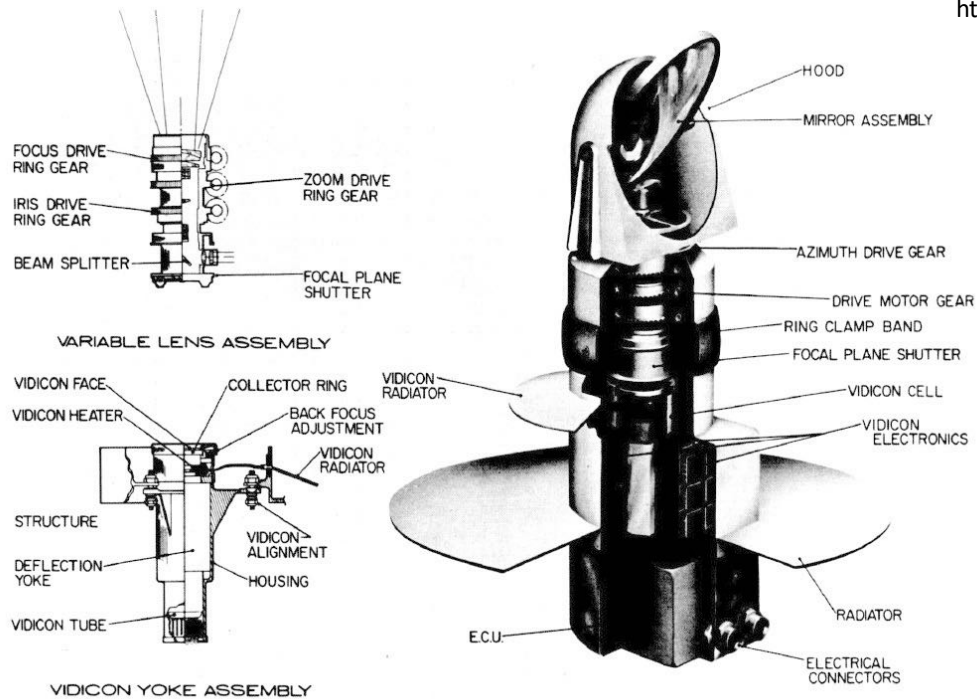


March 24, 1965
Live video from Ranger 9

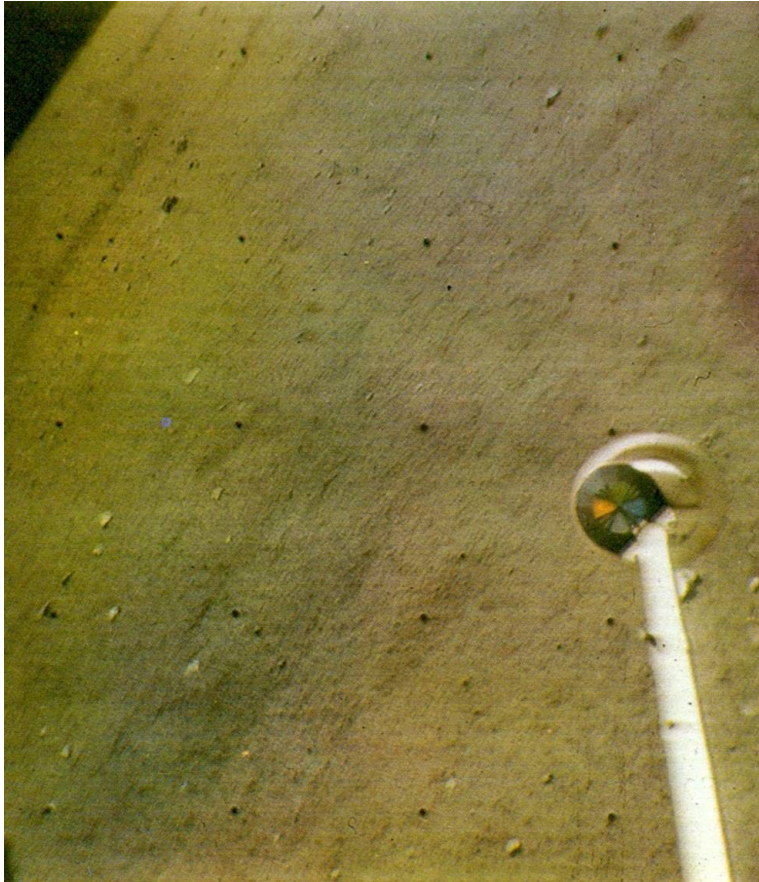


<https://ia801309.us.archive.org/24/items/surveyorprogramr00unit/surveyorprogramr00unit.pdf>

<https://www.drewexmachina.com/2017/04/17/surveyor-3-touching-the-face-of-the-moon/>



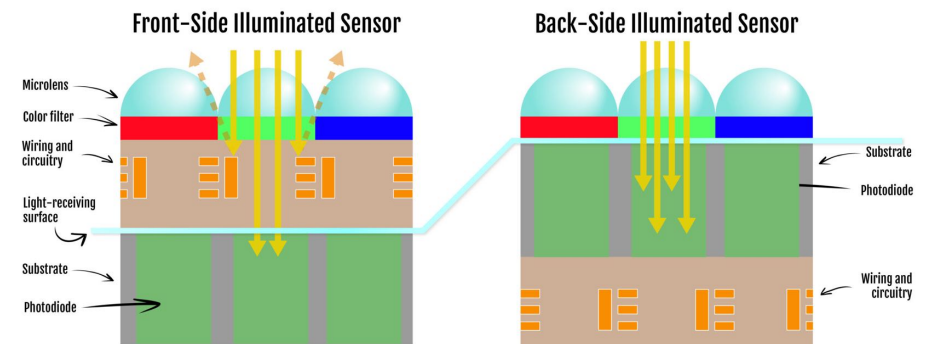
The camera provided a resolution capability of approximately 1 mm at 4 m and could focus from 1.23 m to infinity. The mirror assembly contained a command-able filter wheel mechanism which was capable of accommodating four separate sections of optical-quality glass filters— red, green, and blue, plus a clear section (missions I-V, and polarizing. filters on missions VI and VII). <https://sic.lpl.arizona.edu/surveyor-digitization>



<https://www.collectspace.com/news/news-112219a-apollo-12-surveyor-parts-50-years.html>

Composite of three images taken through red, blue, and green filters to create a color view of the lunar surface.

<https://www.nasa.gov/history/55-years-ago-surveyor-1-makes-a-soft-landing-on-the-moon/>



Modern CMOS Sensor

During the second EVA of Apollo 17, Gene Cernan and Harrison Schmitt were exploring the magnificent Shorty Crater at Station 4, when Schmitt chanced upon some orange soil.

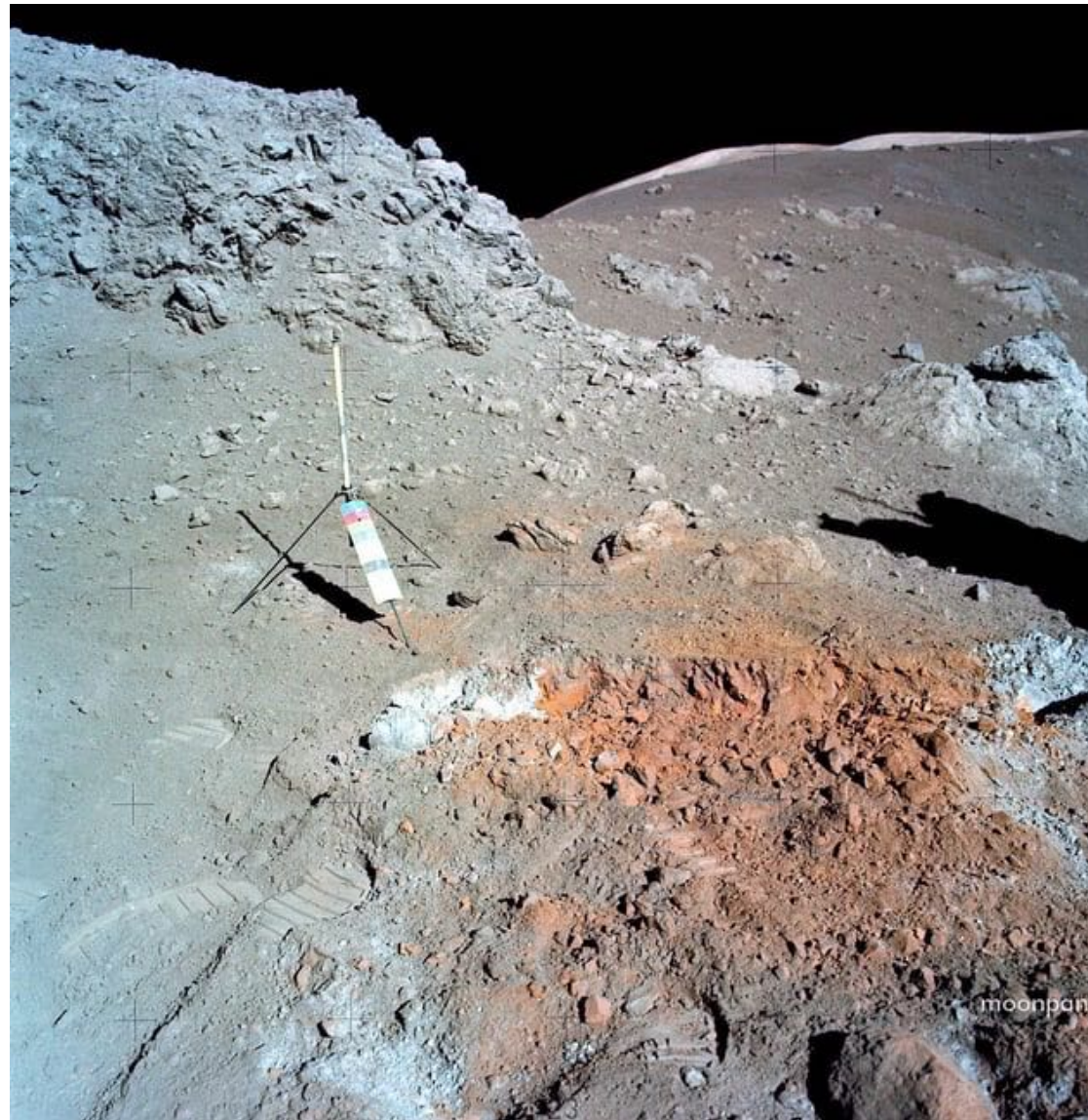
Composition: The soil consists of ~99% volcanic glass spherules, which are rich in titanium and iron.

Origin: It is believed to be the result of a "fire fountain" eruption, where escaping gas expelled lava that cooled instantly into tiny glass beads.

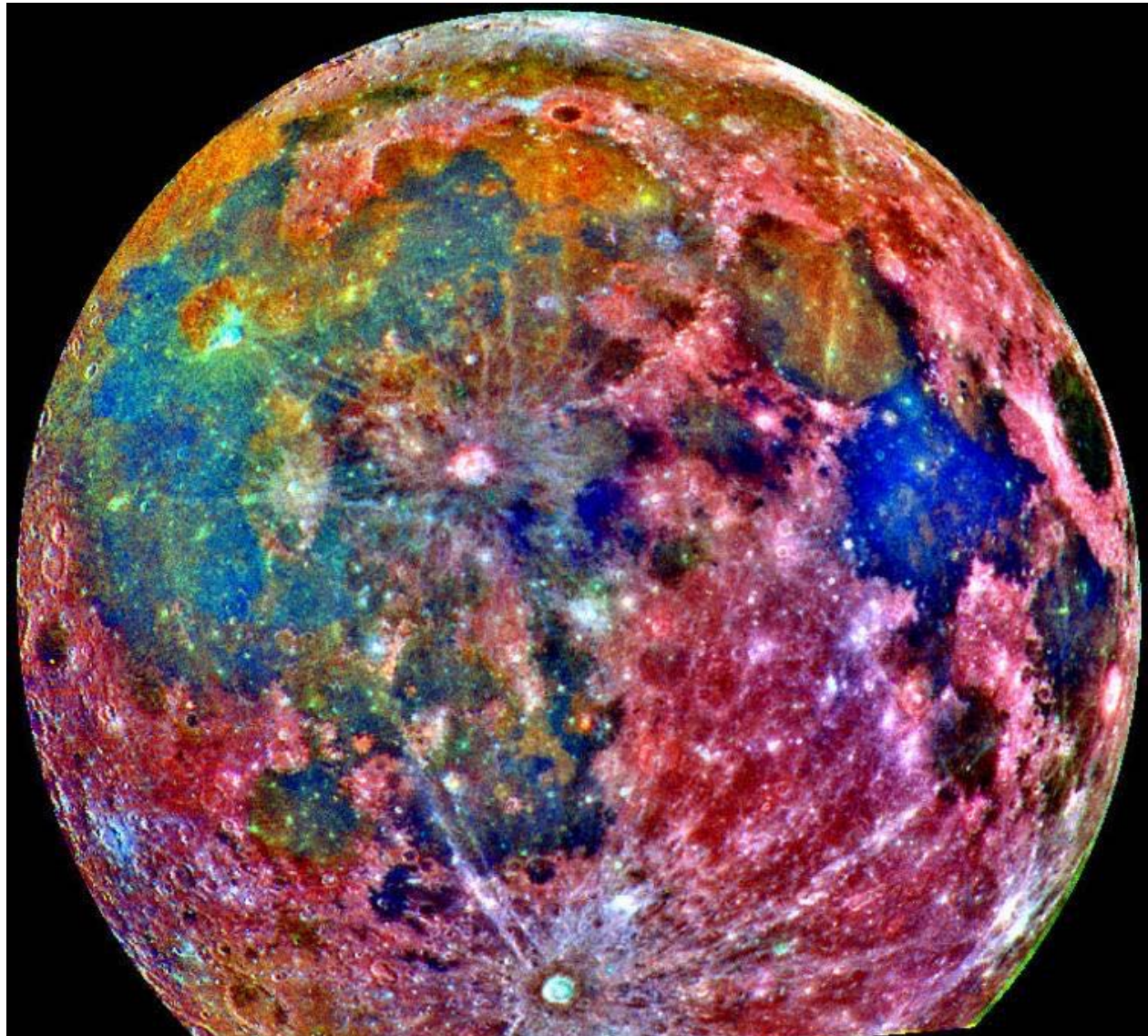
Age: Study of the samples indicates the eruption occurred about 3.7 to 3.75 billion years ago.

Significance: It was a groundbreaking discovery confirming that the Moon had active, explosive volcanism early in its history.

<https://airandspace.si.edu/stories/editorial/food-flight-harrison-schmitts-chili>



The crazy, patchwork appearance of [the false-color image](#) makes this almost full [view of the Moon's](#) familiar [near side](#) look very strange. The Sea of Tranquillity ([Mare Tranquillitatis](#)) is the bright blue area at right, the Ocean of Storms (Oceanus Procellarum) is the extensive blue and orange area on the left, and white lines radiate from the [crater Tycho](#) at bottom center. Recorded in 1992 by the Galileo spacecraft enroute to Jupiter, the picture is a mosaic of 15 images taken through three color filters. The image data were combined in an exaggerated color scheme to emphasize [composition differences](#) - blue hues reveal titanium rich areas while orange and purple colors show regions relatively poor in titanium and iron.



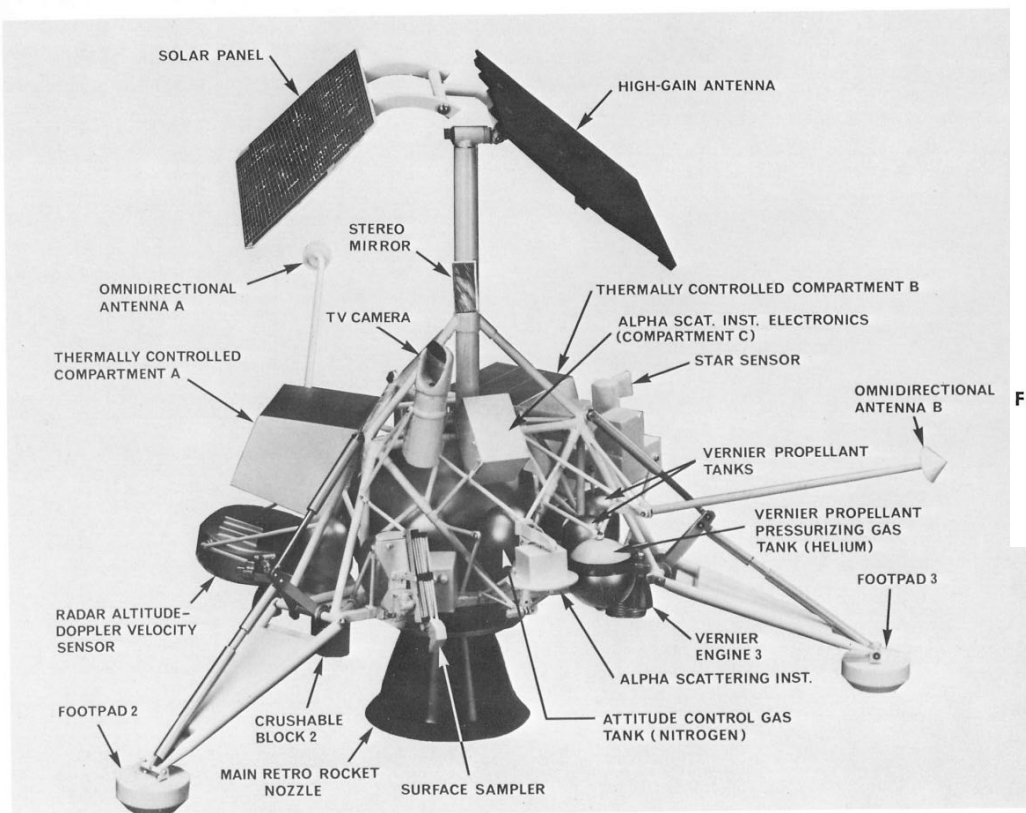
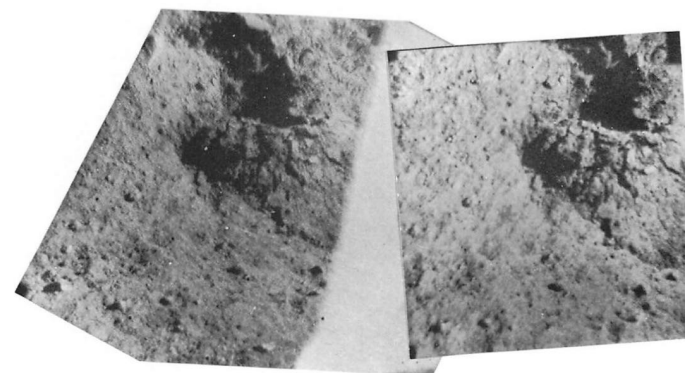


Fig. I-1. Model of Surveyor VII spacecraft



012-003014

Az +6
El -45

Fig. I-2. Stereograms

(Pictures on the right are direct camera views; pictures on the left are auxiliary stereo mirror views and were printed by reversing the negatives and enlarging to compensate for the stereo mirror and the additional mirror distance, respectively. The stereo mirror is shown in Fig. I-1.)

JPL TECHNICAL REPORT 32-1264

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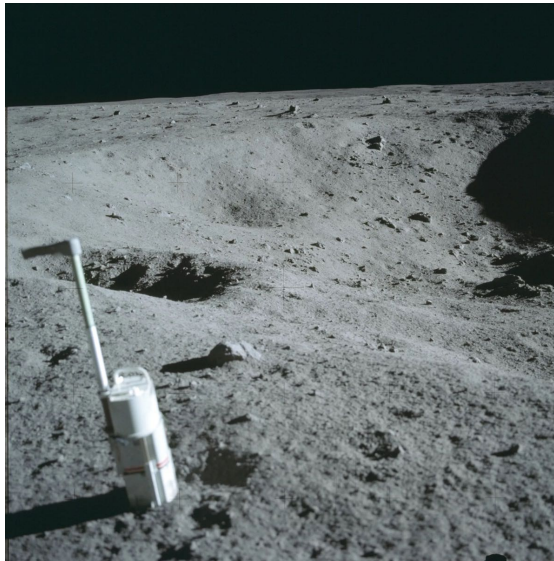
Save 8% on 3 select item(s)

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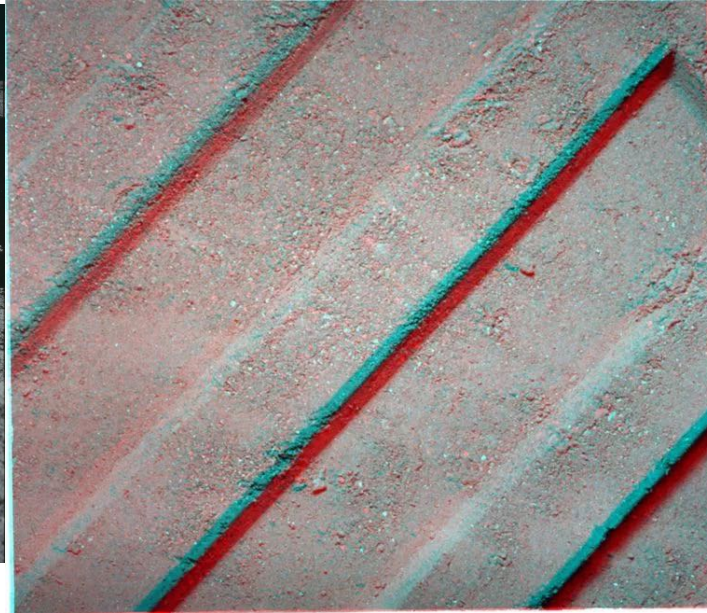
FREE delivery Tomorrow, May 5

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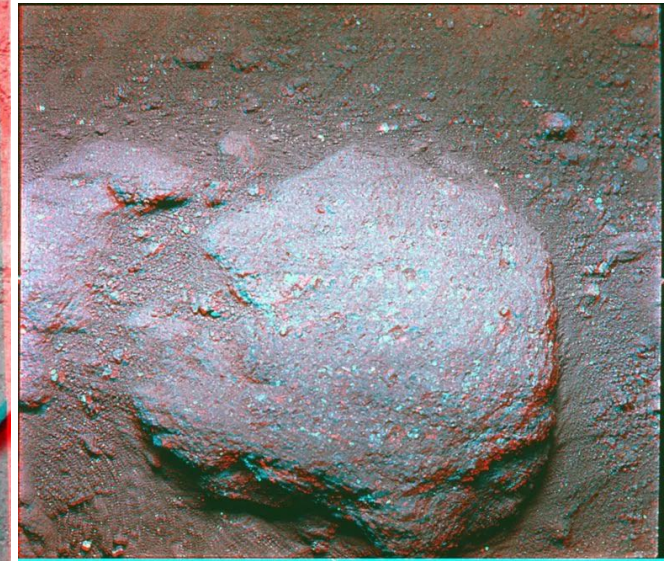
True Stereoscopic Camera Apollo Lunar Surface Closeup Camera (ALSCC)



ALSCC ON THE LUNAR SURFACE The Apollo Lunar Surface Closeup Camera (ALSCC) sits on the lunar surface near a rock-strewn crater during the Apollo 11 moonwalk. *Image: NASA / Lunar and Planetary Institute*



ASTRONAUT BOOTPRINT, APOLLO 12 Catalog description: Soil surface disturbed by astronaut boot. *Image: NASA / Lunar and Planetary Institute*



HARD ROCK SURFACE, APOLLO 11 Catalog description: Hard rock surface. *Image: NASA / Lunar and Planetary Institute*



Fujifilm FinePix REAL 3D W3 10.0MP Digital Camera - Black
 Pre-Owned · Fujifilm FinePix F Series · 3D
 ★★★★★ [26 product ratings](#)

\$250.00
 or Best Offer
 +\$13.59 delivery
 Located in United States

garyc9710 100% positive (221)

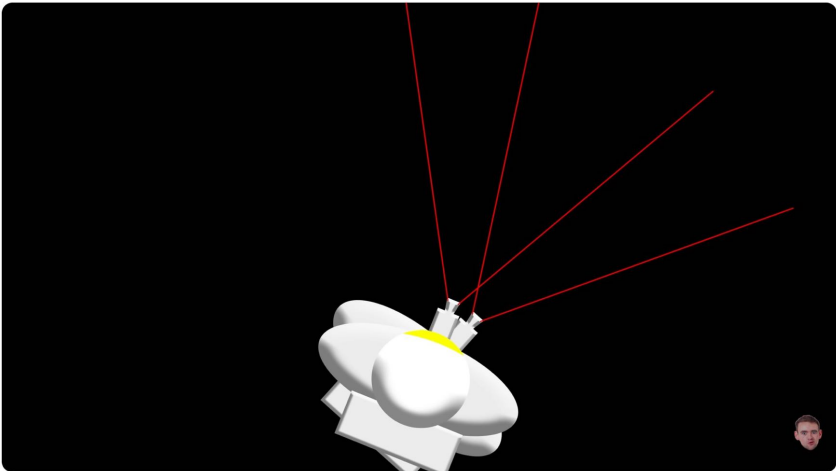


Fujifilm FinePix Real 3D W3 10MP Digital Camera with 3X Optical Zoom-Black
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Stereoscopic Photos generated from “panning photos”



3-D Moon landing photos look AMAZING!!
 Dave McKeegan
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1.8K

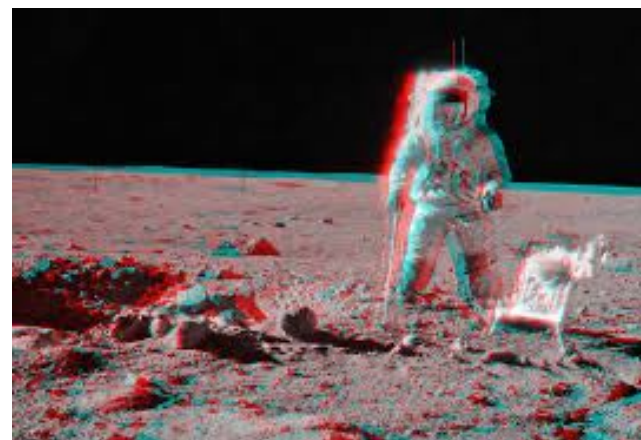
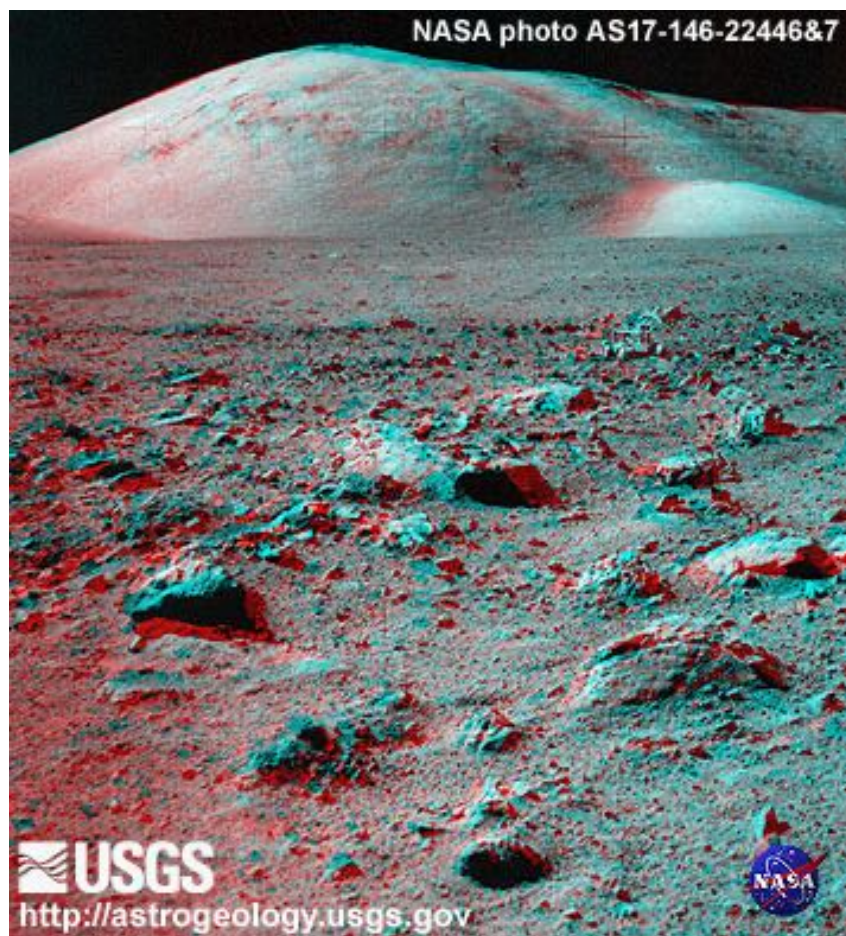
Share Ask Save ...

<https://youtu.be/ceAEe-Cx6e4?si=hv6YeF5wtxCoaCoM>

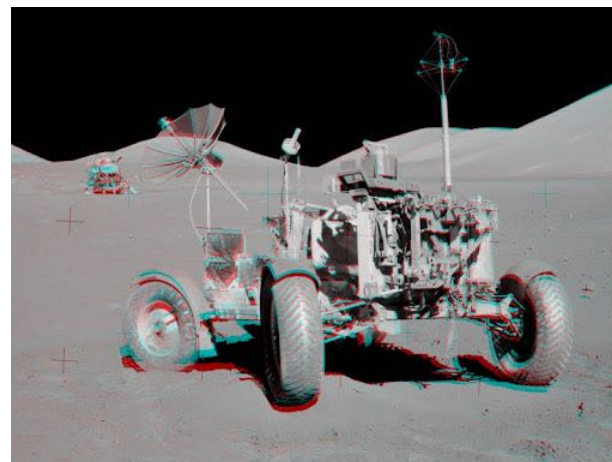
If you’re shooting with a two-lensed 3D camera, like a Fuji W3, then your baseline is already set, and you can’t change it. In this case, you control the depth in your photo by positioning yourself (and your camera) relative to the subject matter. In other words, you might get closer to or farther from your main subject, or choose to keep elements that are very close or very far out of your composition.

Specifically, when shooting with the Fuji W3 or W1, which have a stereo base of about 75 mm, arrange your photo so that the closest and farthest objects in it were at distances corresponding to the values in the table. This will reliably produce images which are suitable for large screen viewing. If you’re displaying your images on a small screen, you can stretch the depth range in your composition a little farther than this.

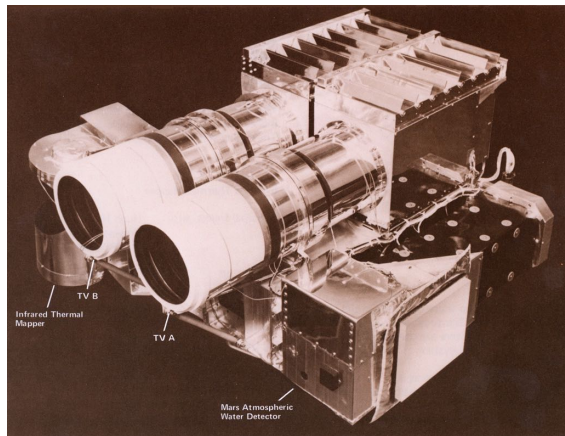
<i>If the closest object in your photo is at this distance</i>	<i>Then the farthest object in your photo should be no farther than</i>
0.75 m	1.2 m
1.2 m	2.1 m
2.1 m	∞



Apollo 17



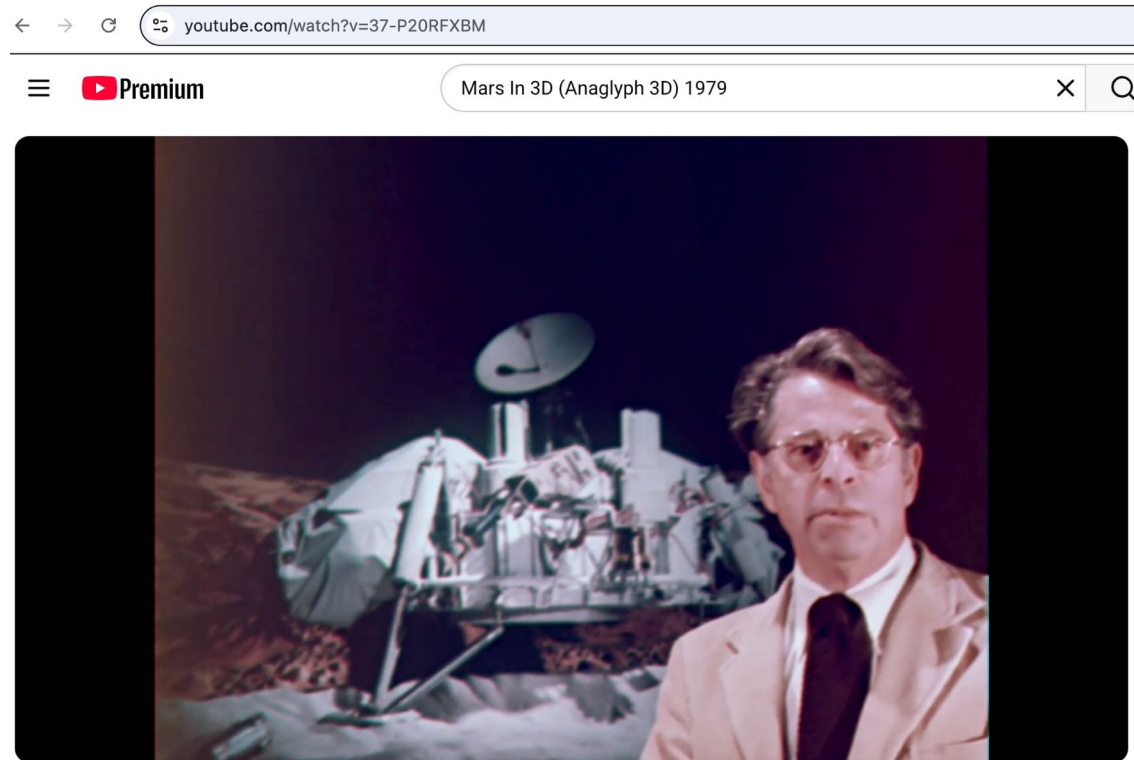
(True Stereoscopic) Viking Stereoscopic Camera (1976)



Viking Orbiter 1

visual imaging subsystem (VIS)

<https://science.nasa.gov/mission/viking/spacecraft-and-science/>



Mars in 3-D (Anaglyph 3D)



Michael McNabb
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3



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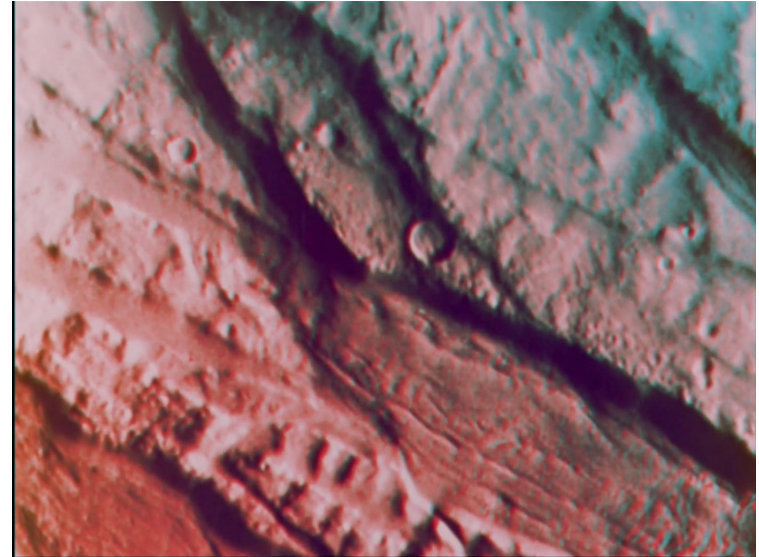
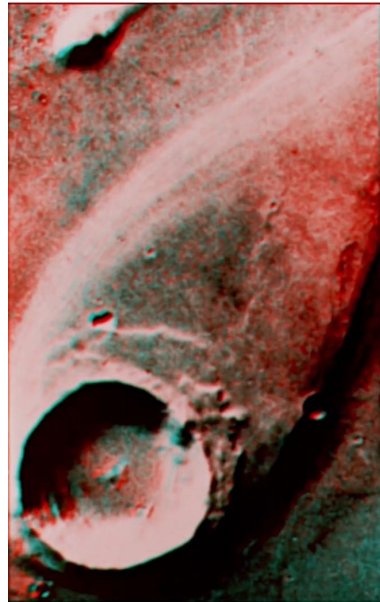
Save

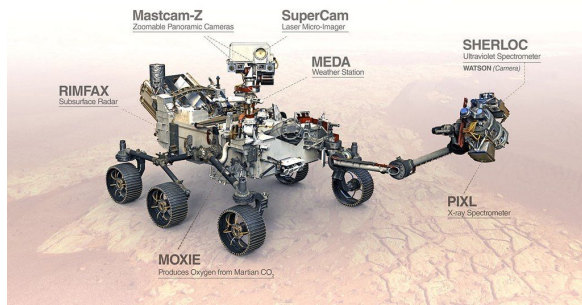


The Viking 1 and 2 landers (1976) used twin, high-resolution cameras separated by 0.8 meters (2.6 feet) and mounted 1.3 meters above the surface to produce [stereoscopic, or 3D, images of Mars](#).

MARS IN 3-D Mars in 3-D is a stereographic film of imagery taken by the NASA Viking 1 and 2 spacecraft from both Mars orbit and on the surface, from both lander locations, between 1976 and 1979. The original film was produced at Stanford University in 1979 using 16mm film. It is a valuable and unique historical presentation of the results of one of the United States' most important space achievements of the decade following the Apollo moon program. The film reels and related materials were eventually donated to the NASA archives at Ames Research Center in Mountain View, CA. *Video: NASA / JPL-Caltech / Stanford University*

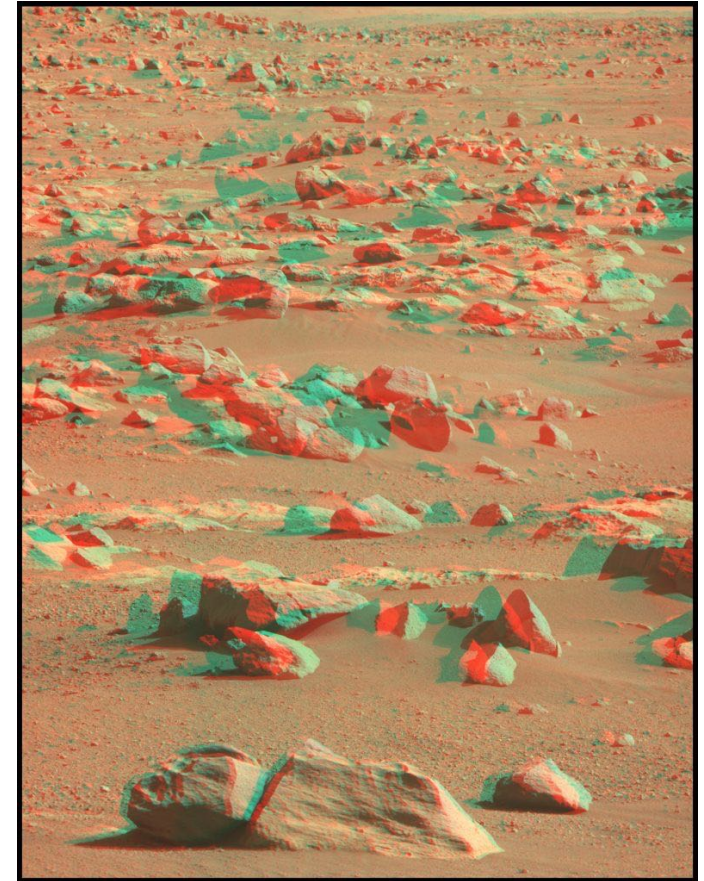
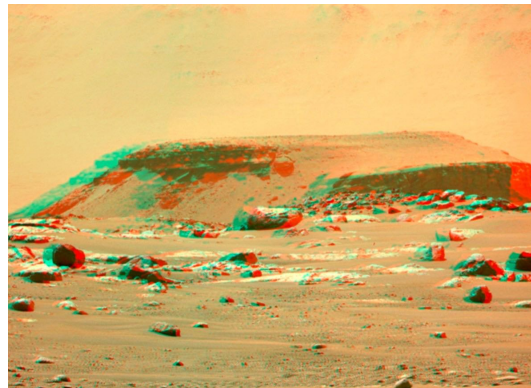
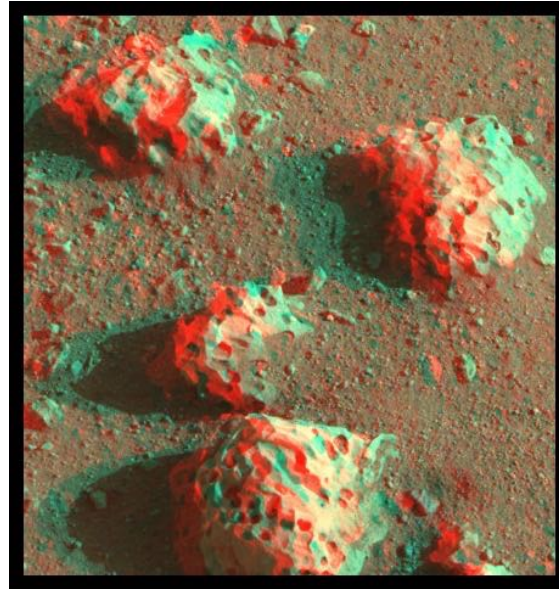
<https://www.planetary.org/articles/3178>





NASA's Perseverance rover is a car-sized robot exploring Mars' Jezero Crater to search for ancient microbial life and collect rock samples for future return to Earth. Landing on February 18, 2021, the rover has traveled over 41 km (25.8 miles) as of April 2026, studying river delta sediments and collecting 23 core samples.

[https://en.wikipedia.org/wiki/Perseverance_\(rover\)](https://en.wikipedia.org/wiki/Perseverance_(rover))



<https://mastcamz.asu.edu/mars-rocks-stereoscopic-corner-3/>

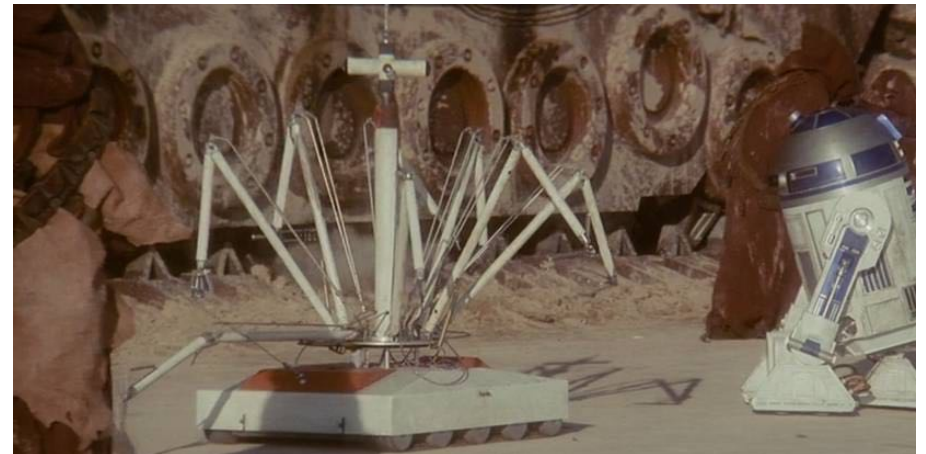


Extendable arm was used on Surveyor Lunar Landers 3, 4 and 7.

Arm is extendable up to 5 feet and able to range over an area of 24 square feet.

https://airandspace.si.edu/collection-objects/lunar-lander-surveyor-soil-mechanics-surface-sampler/nasm_A19700114000

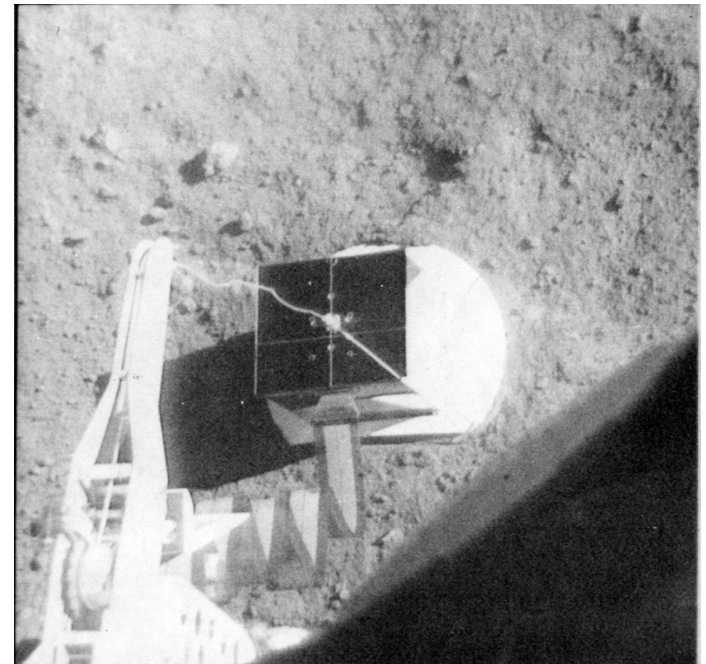
Surveyor 7: About 21 hours after landing, ground controllers fired pyrotechnic charges to drop the alpha-scattering instrument onto the surface. When the instrument failed to move beyond an intermediate position, controllers used the surface sampler to force it down. The sampler was then used to pick up the alpha-scattering instrument after its first chemical analysis and move it to two additional locations. About 66 hours of alpha-scattering data were obtained during the first lunar day on three samples: the undisturbed lunar surface, a Moon rock, and an area dug up by the surface sampler. The alpha-scattering instrument collected 34 more hours of data during the second lunar day. The scoop on the sampler's arm was used numerous times for picking up soil and digging trenches, and for conducting at least 16 surface-bearing tests.



https://starwars.fandom.com/wiki/WED_Treadwell_repair_droid/Legends



SURVEYOR 7 SCOOP ANIMATION Surveyor 7 scoops the lunar surface.*Image:*
NASA / JPL-Caltech / Lunar and Planetary Laboratory / Animation by Jason
Davis
<https://www.planetary.org/articles/20151123-surveyor-digitization-project-update>



First “chemistry set” on the moon
Photo No.: 67-H-1224
(Note String)

Self Rescue using scoop!

To get future Google Chrome updates, you'll need Windows 10 or later. This computer is using Windows 7.

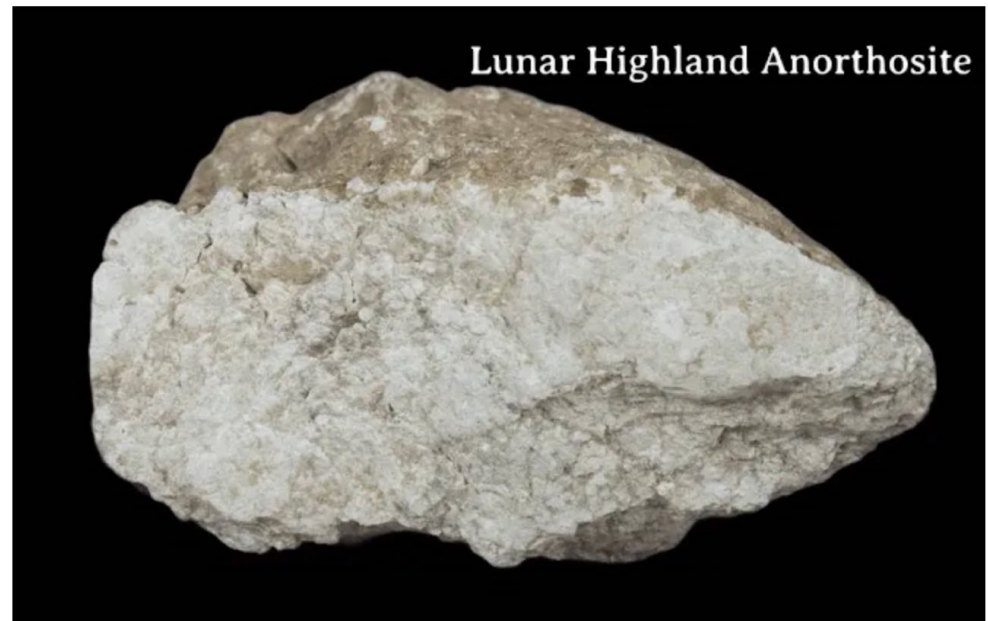
[Learn more](#) X



Anorthosite: A coarse-grained crystalline rock consisting mostly of calcic plagioclase (>90%, usually labradorite) with <10% mafics. The mafic mineral may be clinopyroxene, orthopyroxene, olivine, or, more rarely, amphibole. Oxides, mostly magnetite or ilmenite, are also common. (Mindat)



Apollo 16: Charles Duke at Outhouse Rock, North Ray Crater
(AS16-116-18649)



Lunar highland anorthosite - intrusive plutonic igneous rock composed of calcium-rich plagioclase feldspar from the Moon's primordial crust, Collected by Apollo 16.

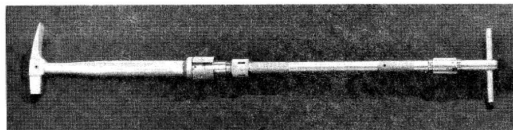


Fig. 32. Lighter weight hammer attached to extension handle for use as a hoe (NASA photo S60-31849).

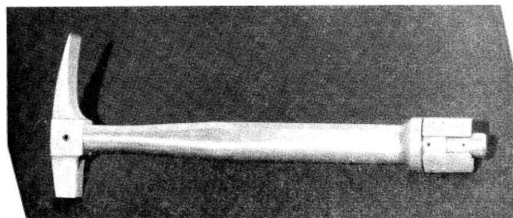


Fig. 33. Lighter weight hammer of the type used on Apollo 11 and 12 (NASA photo S69-31847).

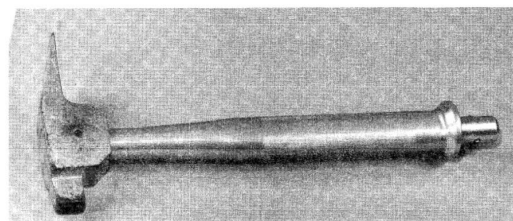


Fig. 34. Heavier weight hammer of the type used on Apollo 14, 15, 16, and 17 (NASA photo S71-22471).



Common Rock Hammer

Weight	Overall Length
14 oz / 392 g	11" / 279 mm
22 oz / 616 g	13" / 330 mm

A. TOOLS AND CONTAINERS USED TO COLLECT LUNAR ROCKS AND SOILS

Contact Soil Sampling Device
 Contingency soil sampler
 Core tube
 Drill
 Extension Handle
 Hammer
 Lunar rover soil sampler
 Rake
 Scoop
 Tongs
 Trenching tool

Two basic styles of hammers (Figs. 31-34) were used on the moon. The model used on later missions was heavier with more surface area on the side of the hammer head.

USE: This tool was used to break chips from rocks or to drive core tubes into the soil (Figs. 31 and 27) It was designed to be used as a hoe for digging furrows when attached to an extension handle (Fig. 32).

MANUFACTURER: NASA, Johnson Spacecraft Center

MATERIALS: The hammer head on both styles of hammers was made of tool steel [AISI S5] which was coated with vacuum deposited aluminum. The handles on both styles were made of aluminum alloy 6061-T6.

LIGHTER WEIGHT HAMMER

WEIGHT: 860 g 142 g on moon
DIMENSIONS: 41 cm overall length
 16 cm hammer head length
 3.8 cm hammer head thickness

APOLLO MISSIONS: Hammers of this style were used on Apollo 11 and 12 (Fig. 33)

HEAVIER WEIGHT HAMMER

WEIGHT: 1300 g 216 g on moon
DIMENSIONS: 39 cm overall length
 16 cm hammer head length
 3.8 cm hammer head thickness

APOLLO MISSIONS: Hammers of this style were used on Apollo 14, 15, 16 and 17. However, there were minor changes in configuration of the handle and adapter through out these missions.



Fig. 5. Space-suited person testing contingency soil sampler in simulated lunar regolith (NASA photo S69-31048).

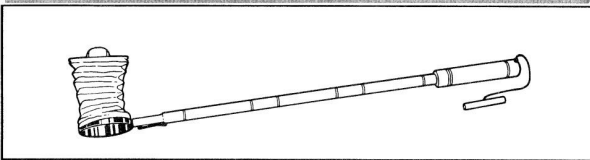
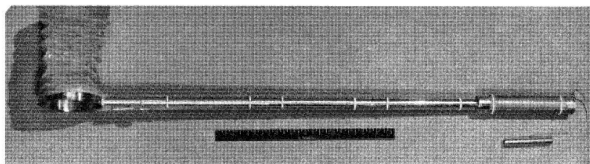


Fig. 6. Contingency soil sampler in extended configuration (NASA photo S68-54937, drawing from [35]).

These trends are illustrated in Figs. 105 and 106. Figure 106 also shows that the collecting tools and containers became more efficient with each mission, since the sample weight increased much faster than the the weight of tools required to collect the samples. The tool and container weight actually decreased on the last mission.



Fig. 31. Heavier weight hammer in use on Apollo 15 (NASA photo AS15-82-11140).

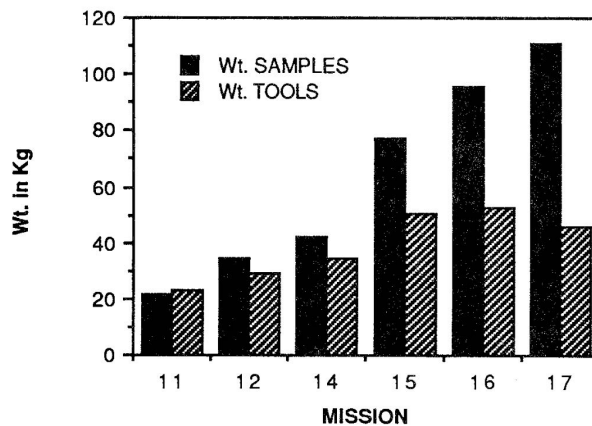


Fig. 106. The weight of samples collected and the weight of the sample collecting tools and containers for each Apollo mission

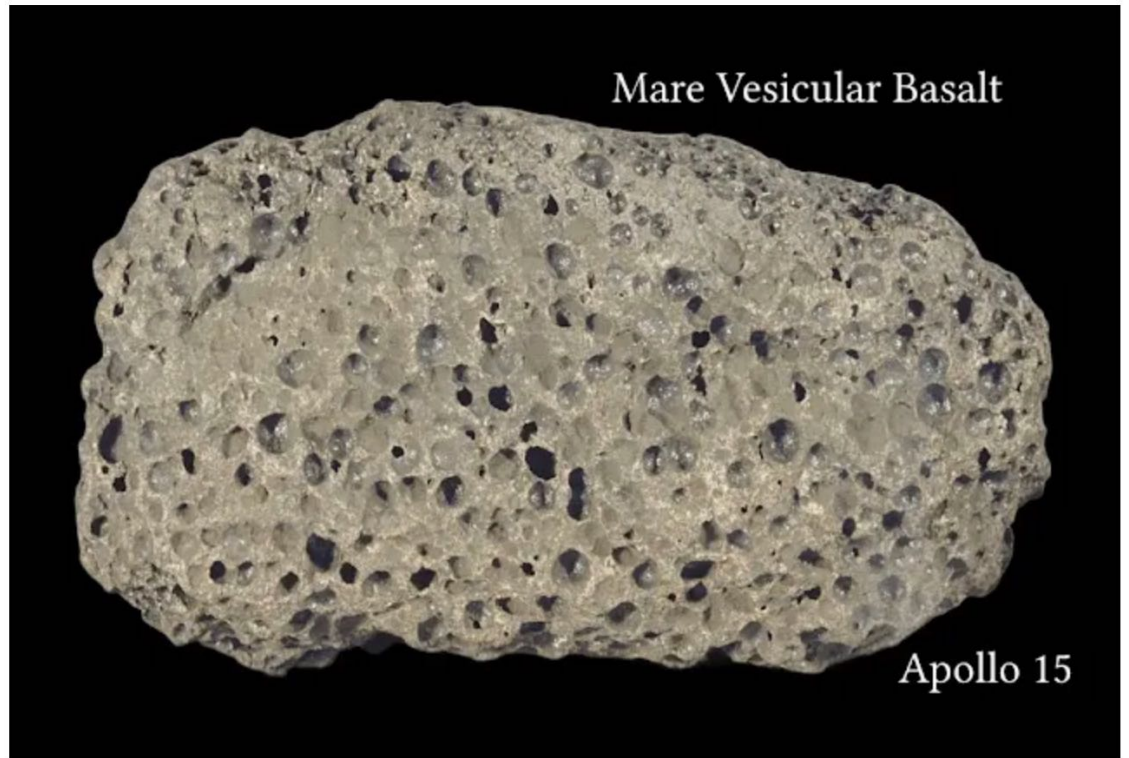
<https://www.lpi.usra.edu/captem/lisac/alltonLunarToolCatalog.pdf>



Fig. 8. A 2-cm diameter core tube, attached to a shorter style extension handle, is being driven into the regolith at the Apollo 12 site (NASA photo AS12-49-7243).



Astronaut James Irwin uses scoop - Apollo 15



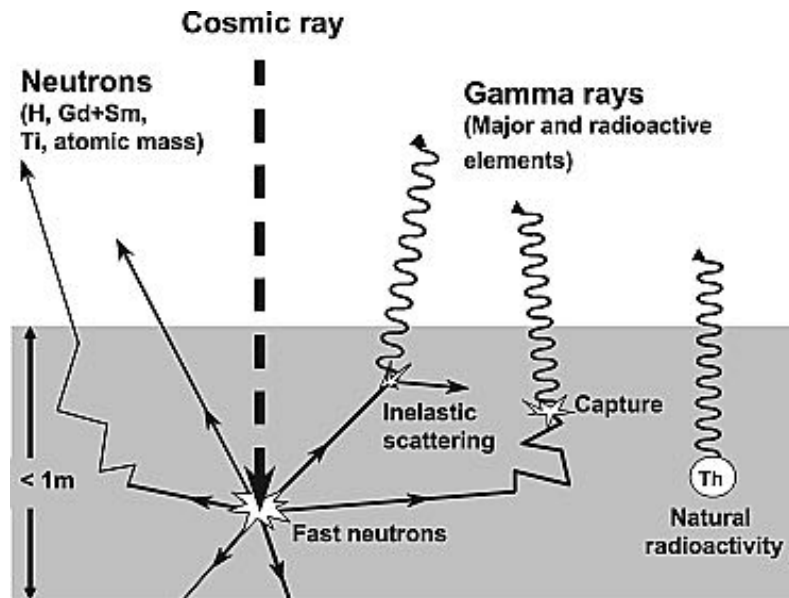
Apollo 15: Mare Vesicular basalt with gas cavities, showing lunar volcanic activity in the Moon's dark plains (maria).



Hybrid Rocket Motor Test (2005)



Remote Sensing – Elemental Identification



Galactic cosmic rays, mainly energetic protons, collide with nuclei in the lunar surface producing a shower of energetic particles, including neutrons and secondary protons. Both neutrons and protons cause nuclear reactions that produce gamma rays; however, for galactic cosmic ray interactions, neutrons are responsible for most of the gamma ray production. The neutrons collide with the nuclei in the surface, losing energy until they escape or approach thermal equilibrium with the surface material in which they are ultimately absorbed. Characteristic gamma rays for each element in the surface are produced by inelastic collisions with fast neutrons and by thermal neutron capture.

Lawrence, D. J., W. C. Feldman, B. L. Barraclough, A. B. Binder, R. C. Elphic, S. Maurice, and D. R. Thomsen (1998), Global elemental maps of the Moon: The Lunar Prospector Gamma-Ray Spectrometer, *Science*, **284**(5382), 1484–1489.

The Apollo 15 & 16 Gamma-Ray Detector

Close up view of the gamma-ray detector used on Apollo missions, withdrawn from the inner anti-coincidence mantle.

The detector system was composed of a large (7cm diameter by 7 cm long) NaI(Tl) scintillation crystal viewed by a photomultiplier tube, surrounded by a plastic anticoincidence shield. Pulse heights from the scintillator were digitized into 511 channels covering the range in flight of 160 keV to 27.5 MeV (Apollo-15) and 65 keV to 10.5 MeV (Apollo-16).



Gamma-ray and X-ray spectrometers carried in the Service Modules of the Apollo 15 and Apollo 16 spacecraft were employed for compositional mapping of the lunar surface. The objective of the gamma-ray experiment was to measure the natural and cosmic-ray induced activity emission spectrum. At this time, the elemental abundances for Th, U, K, Fe, Ti, Si, and O have been determined over a number of major lunar regions.

NASA Photo ID: S68-03354

Gamma rays from radioactive decay are in the energy range from ten kiloelectronvolts (keV) to 10 megaelectronvolts (MeV),

In astrophysics, gamma rays are conventionally defined as having photon energies above 100 keV and are the subject of gamma-ray astronomy

https://en.wikipedia.org/wiki/Gamma_ray

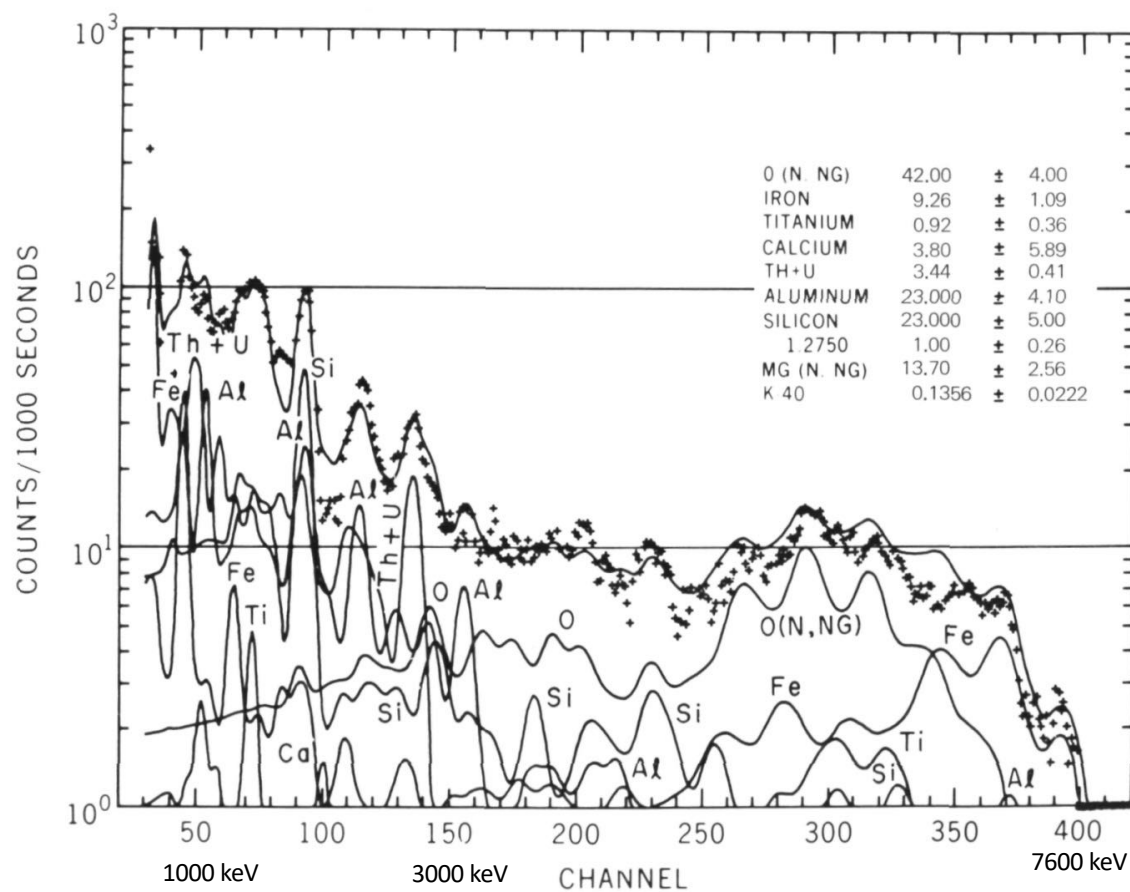
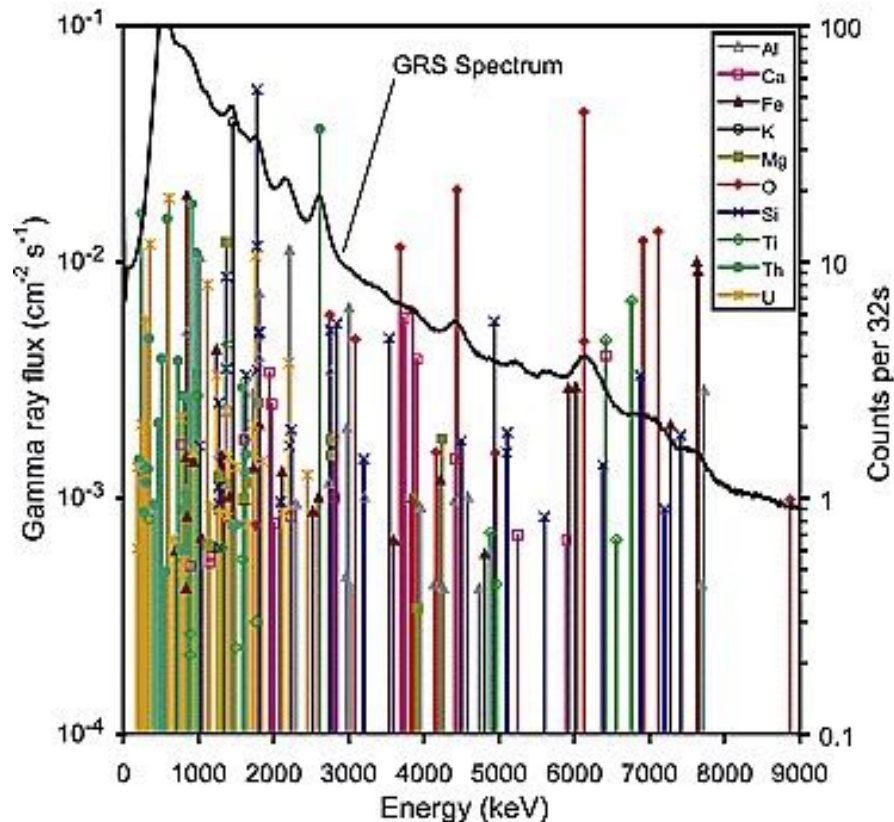


Figure 4.—Difference pulse height spectra or discrete line lunar emission pulse height spectrum obtained with the Apollo 15 gamma-ray spectrometer over the whole ground track. The elemental components for O, Fe, Ti, Co, Th + U, Al, Si, Mg, and K are also indicated. The components were used for the least squares analysis of the difference curve. The synthesized curve obtained from least squares analysis is also shown. Scale is ~ 19 keV/channel.

•Trombka et al. (1977): Lunar elemental analysis obtained from the Apollo gamma-ray and X-ray remote sensing experiment.



To illustrate the information provided by gamma rays, the spectrum of uncollided gamma rays with discrete energies leaking away from the lunar surface (calculated by [Reedy \[1978\]](#)) is shown in [Figure 2](#) for an assumed lunar composition. The gamma rays associated with major elements are produced by nuclear reactions. The gamma rays from K, Th, and U are produced by radioactive decay

Reedy, R. C. (1978), Planetary gamma ray spectroscopy, *Proc. Lunar Planet. Sci. Conf. 9th*, 2961–2984.

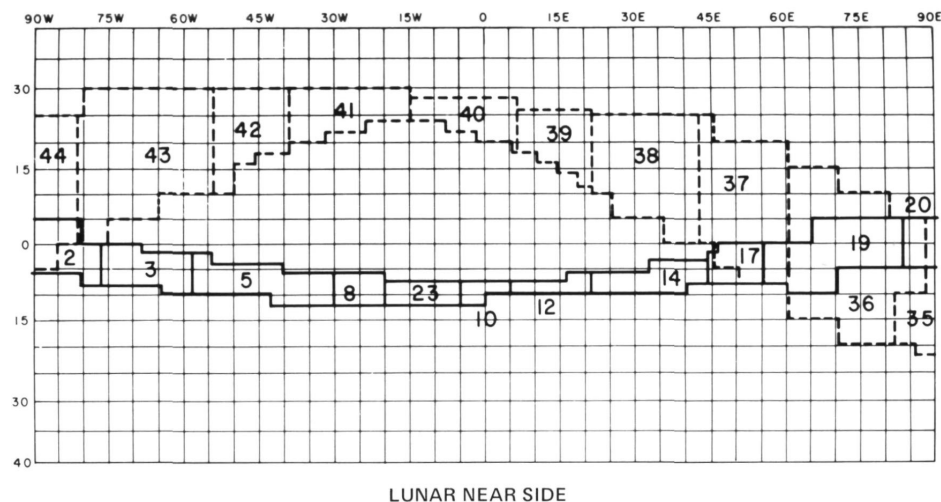


Table 3.—*Apollo 15: Element Concentrations by Regions*

Region	Fe (%)	Mg (%)	Ti (%)	Th (ppm)	K (ppm)
34	7.7	3.8	0.1	2.3	1600
35	6.5	4.5	1.3	1.0	940
36	9.3	5.7	0.8	1.4	1200
37	11.3	7.0	2.2	1.2	1400
38 ⁽¹⁾	(12.1)	(4.8)	(2.9)	1.7	1200
39	10.7	6.6	2.6	2.3	1700
40	8.4 ⁽²⁾	6.3	0.8	6.8	3100
41	13.6	6.2	1.4	5.8	1700
42	9.6 ⁽²⁾	4.9	2.2	6.9	2500
43	10.5	4.6	2.0	3.9	1700
44	5.7	3.5	1.5	0.4	950
All Data	8.7	4.8	1.45	2.2	1230

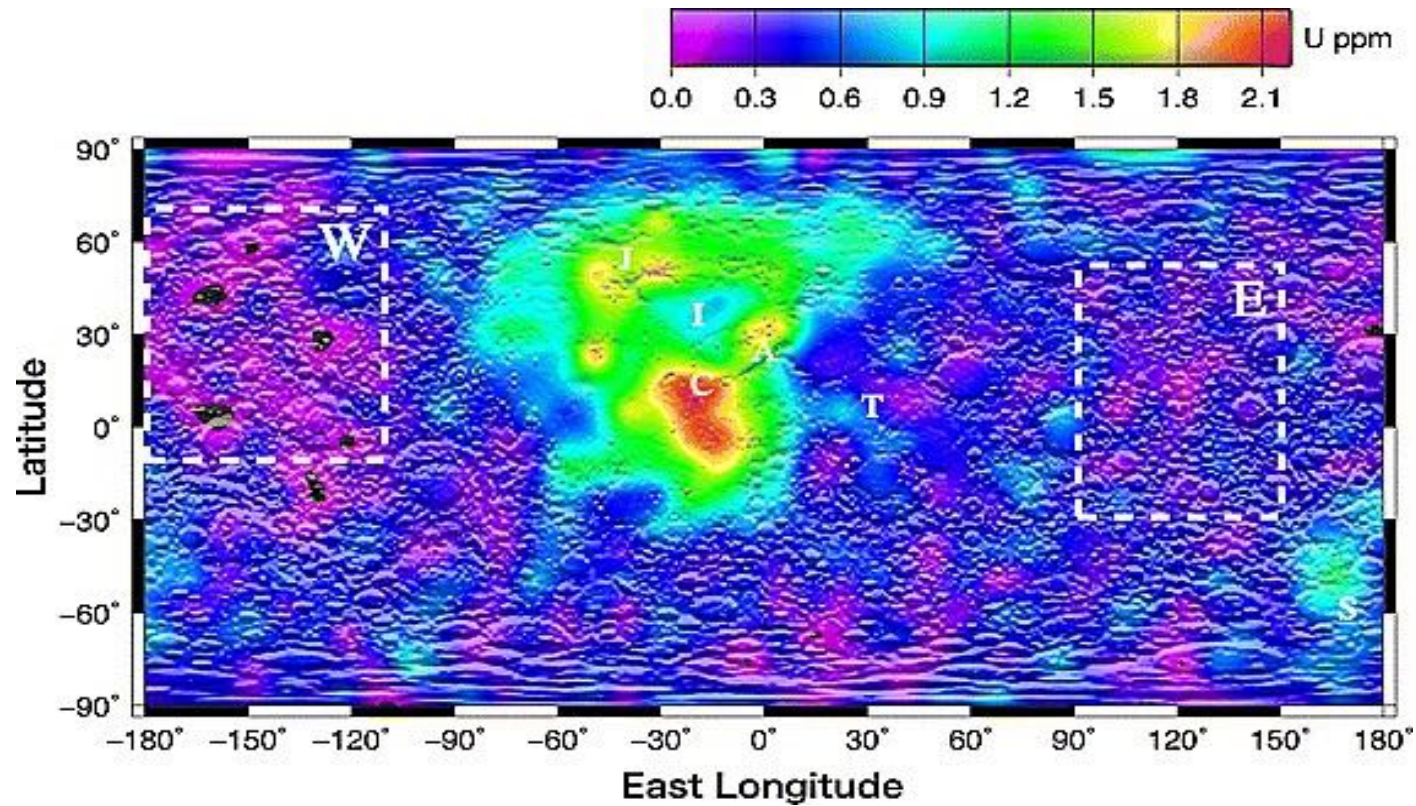
Potassium-feldspar (K-feldspar) contains approximately **40,000 ppm to 140,000 ppm (4% to 14%)** of elemental potassium

Sodic feldspar typically contains a low percentage of potassium (K), generally ranging from **0.5% to 3%** by weight as an impurity (often as solid solution with potassium feldspar)

Lunar Elemental Analysis Obtained From the Apollo Gamma-Ray and X-Ray Remote Sensing Experiment

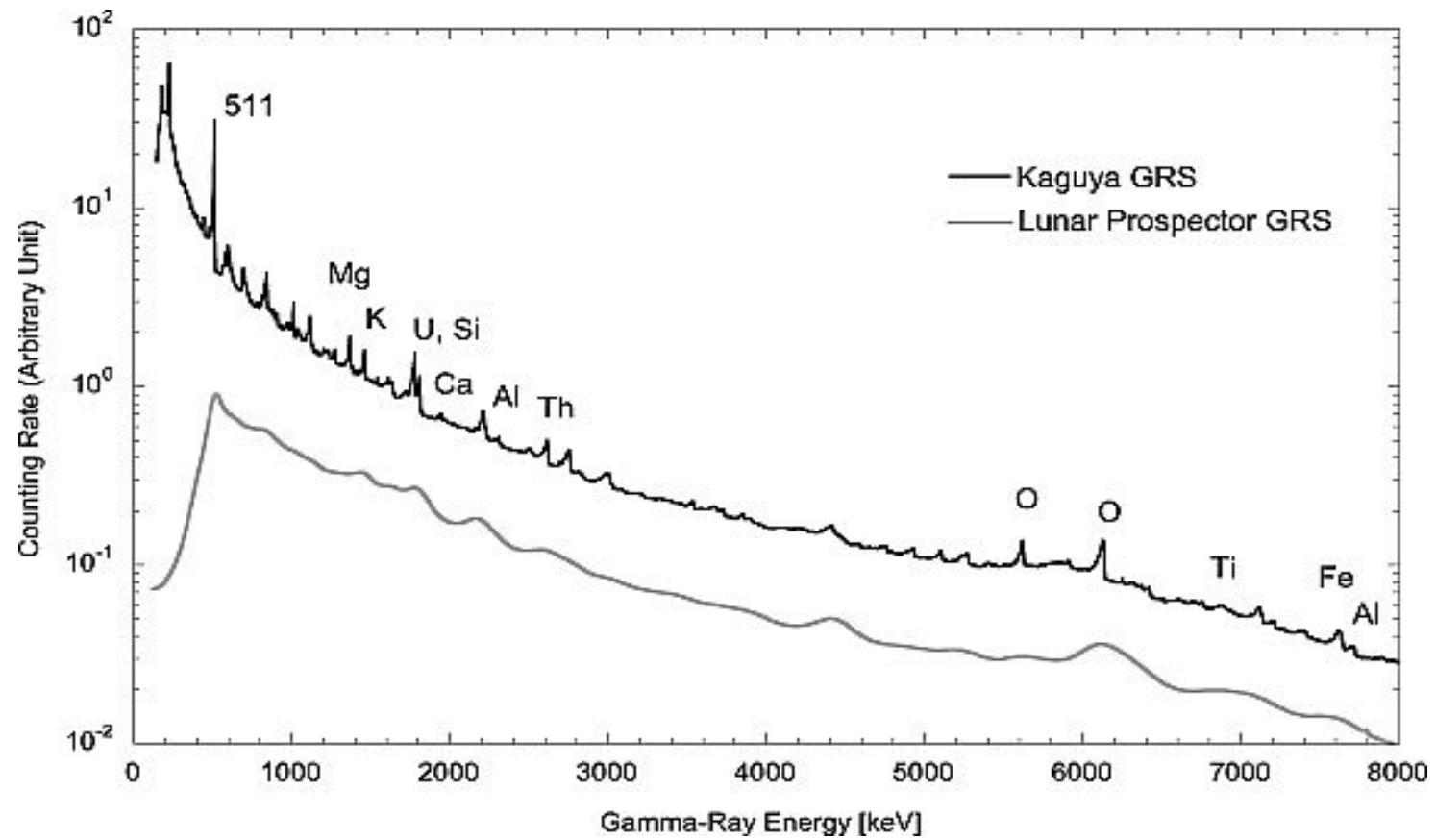
<https://ntrs.nasa.gov/api/citations/19780004991/downloads/19780004991.pdf>

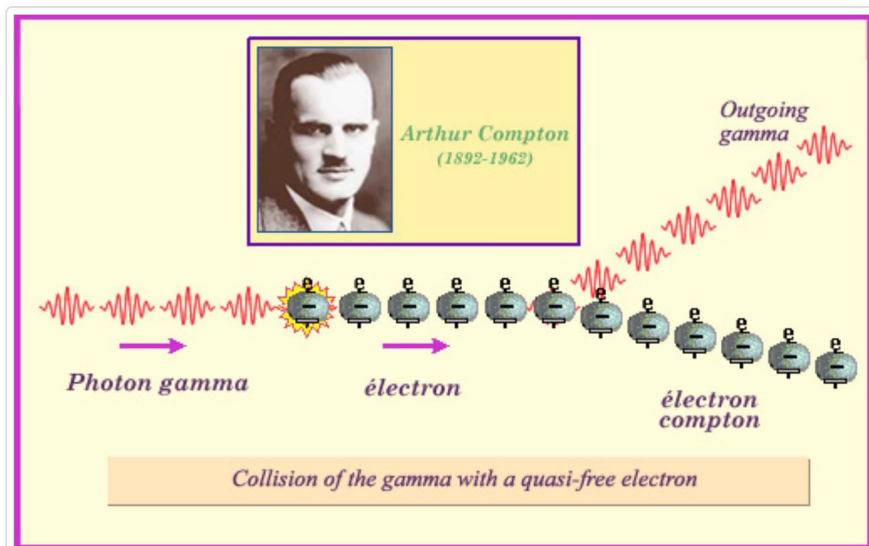
Uranium on the Moon: Global distribution and U/Th ratio



Procellarum KREEP terrain (PKT) up to 2.1 ppm for uranium and 7.3 ppm for thorium
(Kaguya probe (SELENE), launched by JAXA in 2007)

Uranium on the Moon: Global distribution and U/Th ratio





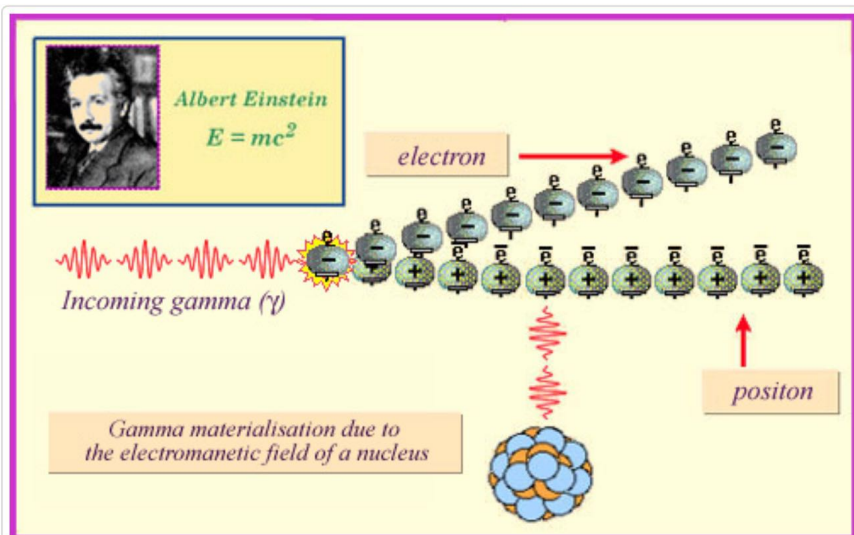
The Compton effect:

This second process is the most common way for gamma photons with mid-level energies to interact with matter. It resembles the photoelectric effect in that gamma rays collide with atomic electrons, but in addition to expelling the electron the photon is replaced by an outgoing photon with a lower energy. The Compton effect predominates when the incoming photon's energy is far greater than that binding the colliding electron to its atom. The process gets its name from the American physicist Arthur Compton.

© IN2P3

Gamma ray energy does not depend on atomic number (Z), unlike photoelectric effect and pair production. Might not be ideal for identifying individual elements. Useful for density analysis.

https://radioactivity.eu.com/articles/phenomenon/gamma_matter

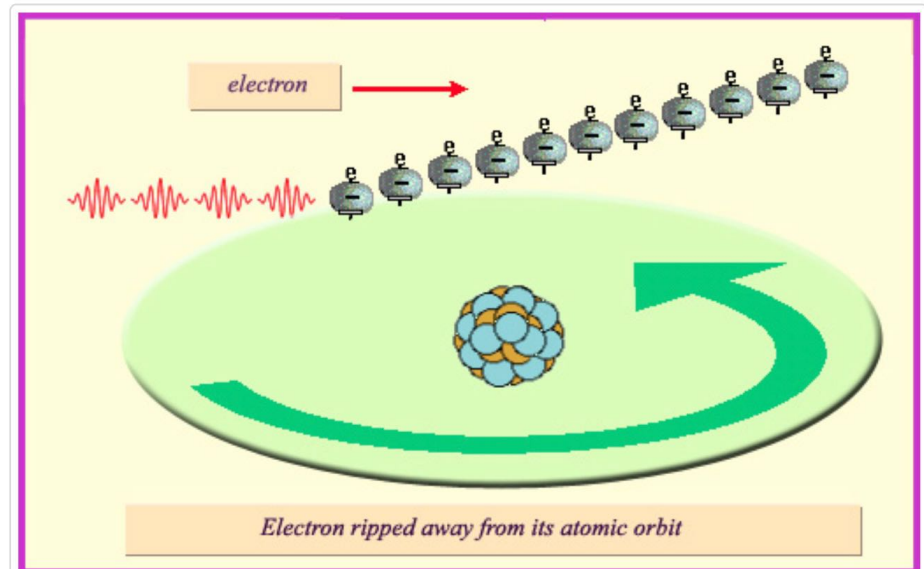


Pair Production

Pair Production is the production of a pair of mutual antiparticles, an electron and a positron. This process only takes place for photon energies above 1.02 MeV, the minimum energy required to create the two particles (according to the $E=mc^2$ Einstein mass formula). The majority of gamma coming out of radioactive decay do not reach this threshold. Pair production occurs mainly with more energetic gamma produced by accelerators or found in cosmic rays.

© IN2P3

Na-22 is a positron emitter



The photoelectric effect:

The photoelectric effect is the most common way for low-energy photons to interact with matter. It also takes place with gamma rays. A gamma collides with an electron orbiting an atom, expelling the electron from its atomic orbit. The electron expulsion is followed by a rearrangement of the atom's electronic cohort to fill the gap. In the process the photon vanishes.

© IN2P3

Emission Product: When the photoelectron is ejected, a vacancy is created, leading to the emission of characteristic X-rays or Auger electrons as the atom relaxes.

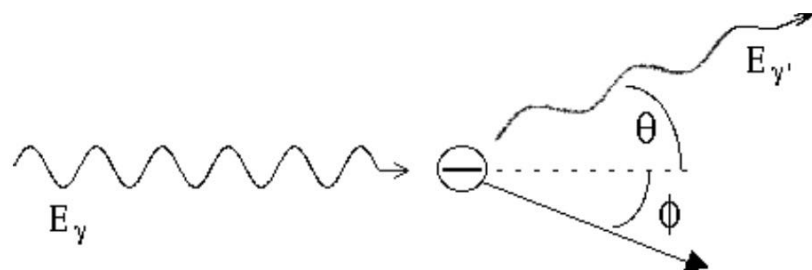


Figure 4.2. Compton-scattering collision between an incoming photon, E_γ , and a stationary electron. This results in a lower energy photon, $E_{\gamma'}$, scattered through angle θ , and the electron scattered through angle ϕ .

SUGGESTED EXPERIMENTAL PROCEDURE

Place a thick lead absorber (say 3-10 mm) a few centimeters beneath the source to sandwich the source between the lead and the detector.

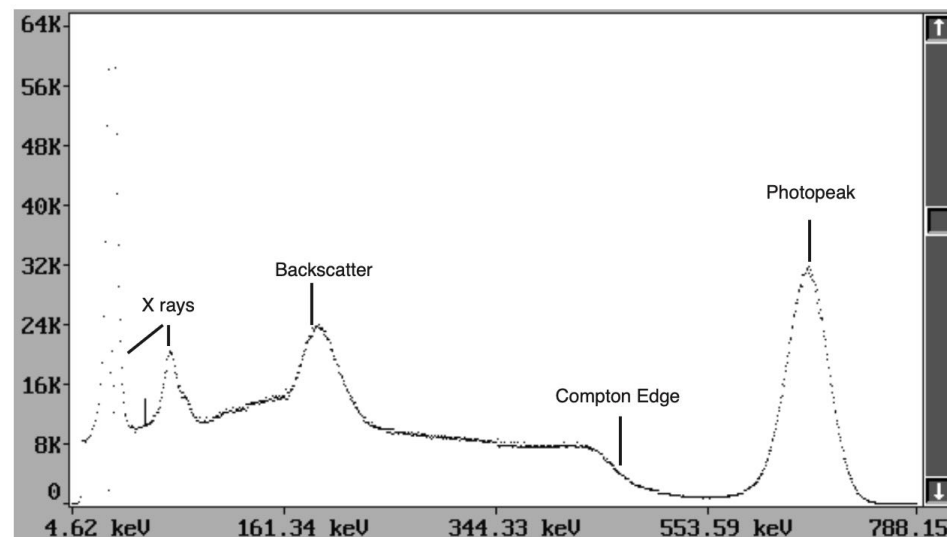
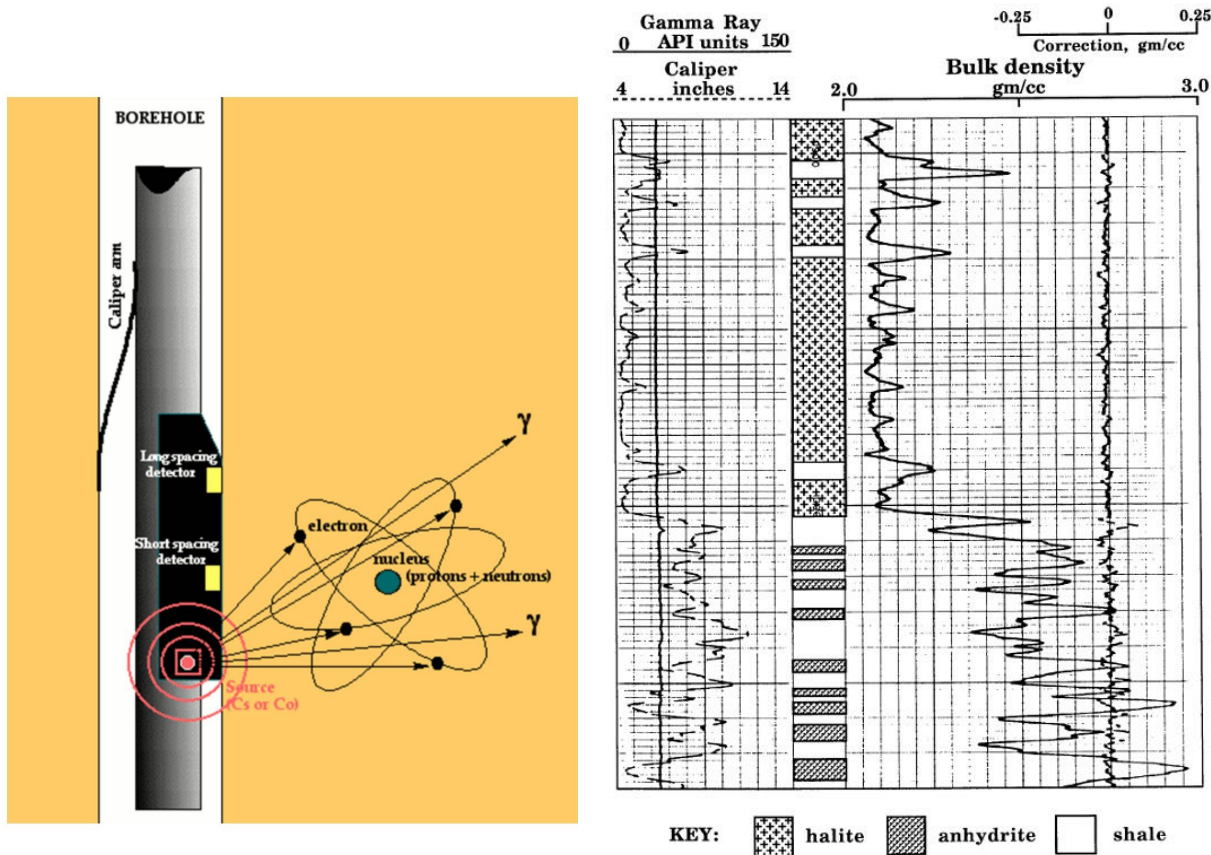


Figure 4.1. Gamma spectrum from the decay of ^{137}Cs .

The backscatter peak in each spectrum should have changed in intensity with the addition of the lead sheet. It is the product of the electron density and the material thickness that correlates directly with the intensity of the backscatter peak.

Density Logging Tool

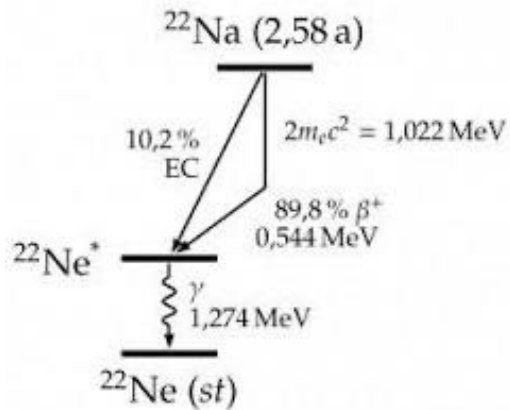
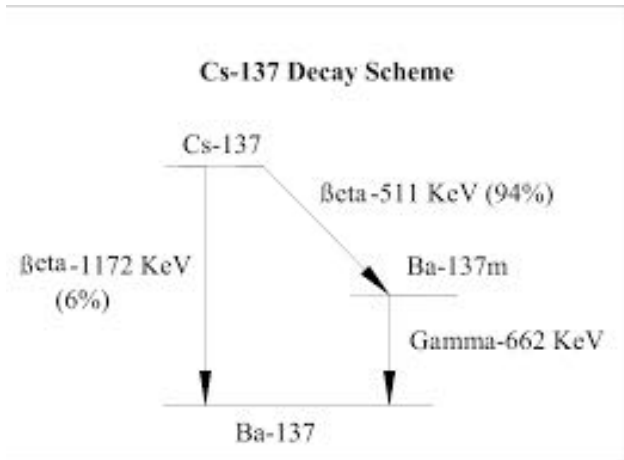


These constant energy gamma rays radiate into the formation and interact with the electron clouds of the atoms they encounter by Compton scattering, photoelectric effect and pair production processes. As a consequence, there is a reduction in the gamma ray flux

The reduction in gamma-ray flux is proportional to the average electron density of the formation. The electron density measurements may be converted to apparent bulk density through considerations of a simple atomic theory. The density curve is scaled in units of grams per cubic centimeter and is referred to as the bulk density.

Mineral	Density (g/cm^3)
Halite	2.04 - 2.16
Gypsum	2.20 - 2.4
Anhydrite	2.2 - 2.98
Carnallite	1.57 - 1.61
Sylvite	1.86 - 1.99
Shale	1.77 - 3.30

Gamma and X-ray Analysis of Materials



drct.com/nuclear/index.php?main_page=product_info&cPath=8&products_id=70

Direct Scientific

Categories: Accessories (1), Marinelli Beakers, Planchets (3), Portable Radiation Detectors (9), Radiation Counters (2), Shielding (6), Sources (16), Dosimeters (6), Area Monitors (11), VCA's (3), Specials (3)

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Product 13/16

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- 10 microCuries ☐ (+\$320.00)

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Home :: Sources :: Sodium-22 Check Source

Product 13/16

Previous Return to the Product

Sodium-22 Check Source

Model: NA22S

Starting at:

Please Choose:

- 1 microCurie ☐ (+\$235.00)
- 5 microCuries ☐ (+\$385.00)
- 10 microCuries ☐ (+\$430.00)

Optional Secondary Calibration

☐ 5% Nominal, gamma sources only. (+\$140.00)

Table of X-ray Emission Lines

3/3

Element		K _{α1}	K _{α2}	K _β	L _{α1}	L _{α2}	L _{β1}	L _{β2}	L _γ	M _α
⁶⁷ Ho	holmium	47.55	46.70	53.88	6.72	6.68	7.53	7.91	8.75	1.35
⁶⁸ Er	erbium	49.13	48.22	55.68	6.95	6.91	7.81	8.19	9.09	1.41
⁶⁹ Tm	thulium	50.74	49.77	57.52	7.18	7.13	8.10	8.47	9.43	1.46
⁷⁰ Yb	ytterbium	52.39	51.35	59.37	7.42	7.37	8.40	8.76	9.78	1.52
⁷¹ Lu	lutetium	54.07	52.97	61.28	7.66	7.60	8.71	9.05	10.14	1.58
⁷² Hf	hafnium	55.79	54.61	63.23	7.90	7.84	9.02	9.35	10.52	1.64
⁷³ Ta	tantalum	57.53	56.28	65.33	8.15	8.09	9.34	9.65	10.90	1.71
⁷⁴ W	tungsten	59.32	57.98	67.24	8.40	8.34	9.67	9.96	11.29	1.78
⁷⁵ Re	rhenium	61.14	59.72	69.31	8.65	8.59	10.01	10.28	11.69	1.84
⁷⁶ Os	osmium	63.00	61.49	71.41	8.91	8.84	10.36	10.60	12.10	1.91
⁷⁷ Ir	iridium	64.90	63.29	73.56	9.18	9.10	10.71	10.92	12.51	1.98
⁷⁸ Pt	platinum	66.83	65.11	75.75	9.44	9.36	11.07	11.25	12.94	2.05
⁷⁹ Au	gold	68.80	66.99	77.98	9.71	9.63	11.44	11.58	13.38	2.12
⁸⁰ Hg	mercury	70.82	68.90	80.25	9.99	9.90	11.82	11.92	13.83	2.20
⁸¹ Tl	thallium	72.87	70.83	82.58	10.27	10.17	12.21	12.27	14.29	2.27
⁸² Pb	lead	74.97	72.80	84.94	10.55	10.45	12.61	12.62	14.76	2.35
⁸³ Bi	bismuth	77.11	74.81	87.34	10.84	10.73	13.02	12.98	15.25	2.42

https://www.horiba.com/fileadmin/uploads/Scientific/Documents/XRay/emission_lines.pdf

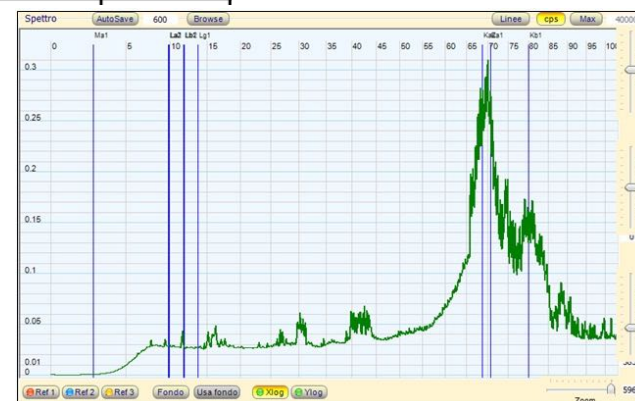
Na-22 Excitation Source

$K_{\alpha 1}$	$K_{\alpha 2}$	K_{β}
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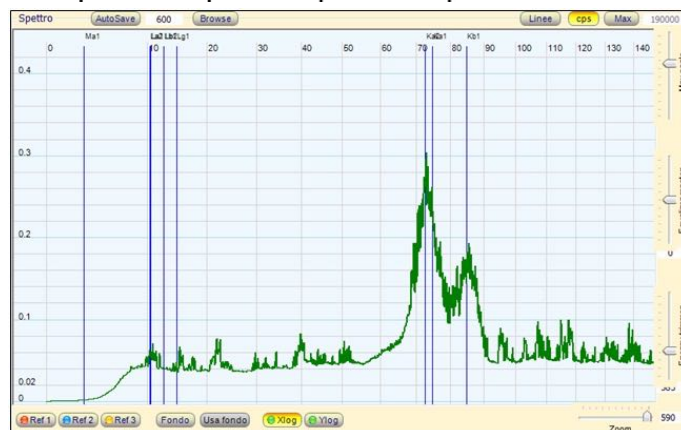
Gold

68.80	66.99	77.98
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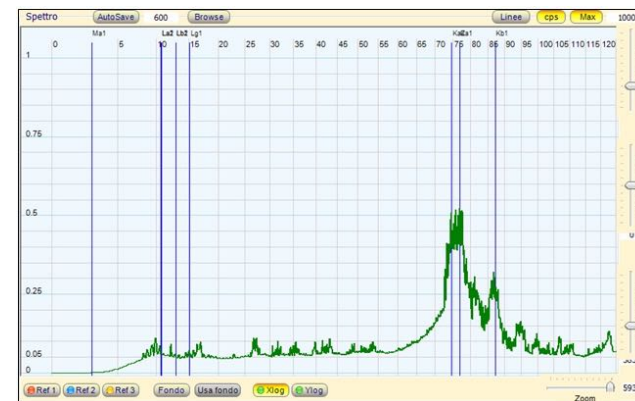
Mercury

70.82	68.90	80.25
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Lead

74.97	72.80	84.94
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Bismuth

77.11	74.81	87.34
-------	-------	-------

<https://physicsopenlab.org/2016/03/08/heavy-elements-xrf-spectra/>



30 keV to 3 MeV (0.03 — 3 MeV),

Radiacode 102

SKU: RC102

Portable radiation detector and spectrometer

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9.5% ±0.4% FWHM

30 cps = 1 μSv/h for Cs-137

Type-C

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What's in the box

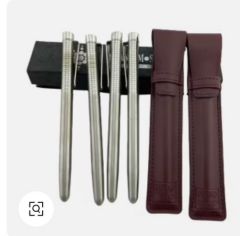
Radiacode Spectrum Thorium232



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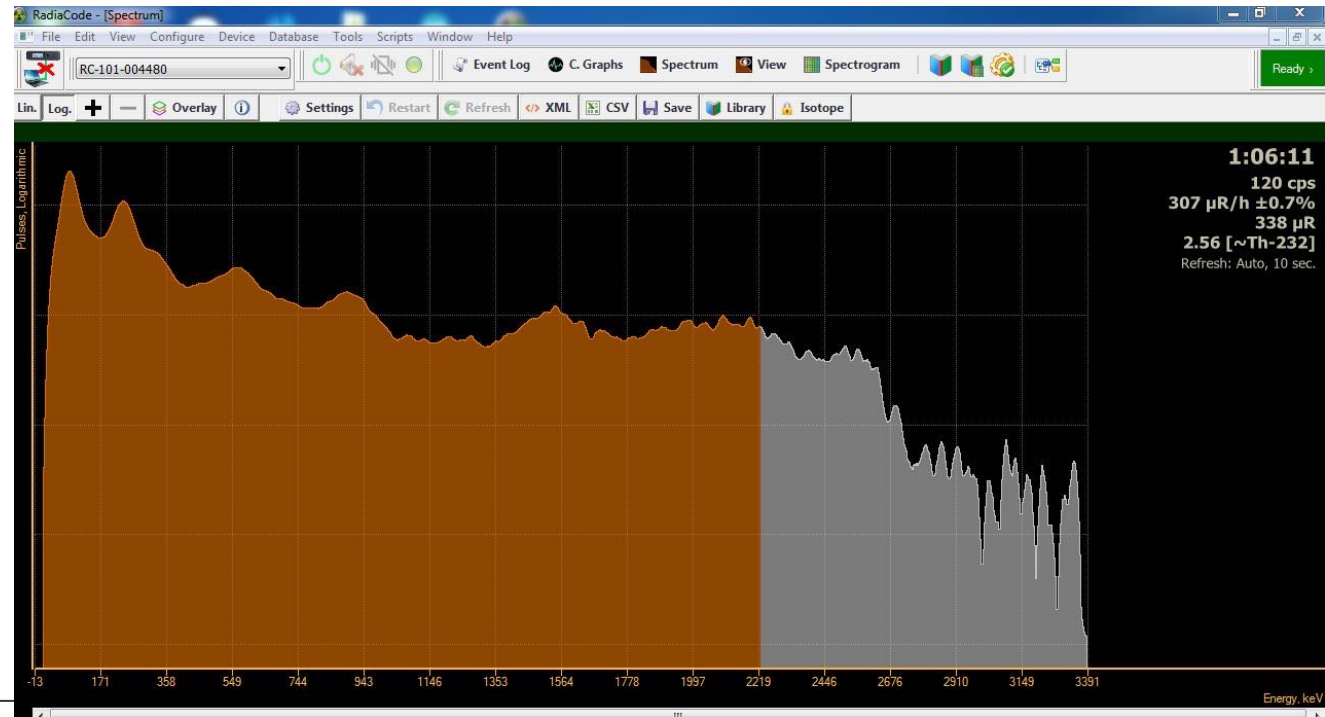


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Tl-208

Thallium-208

β , γ radiation

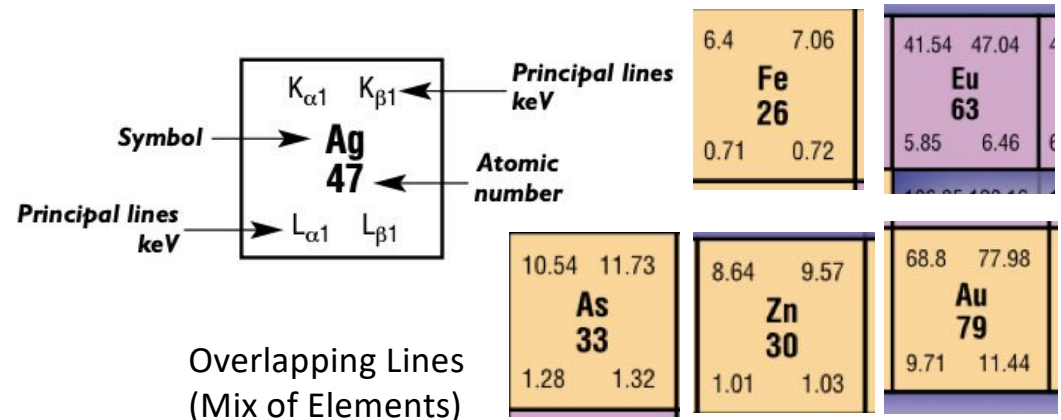
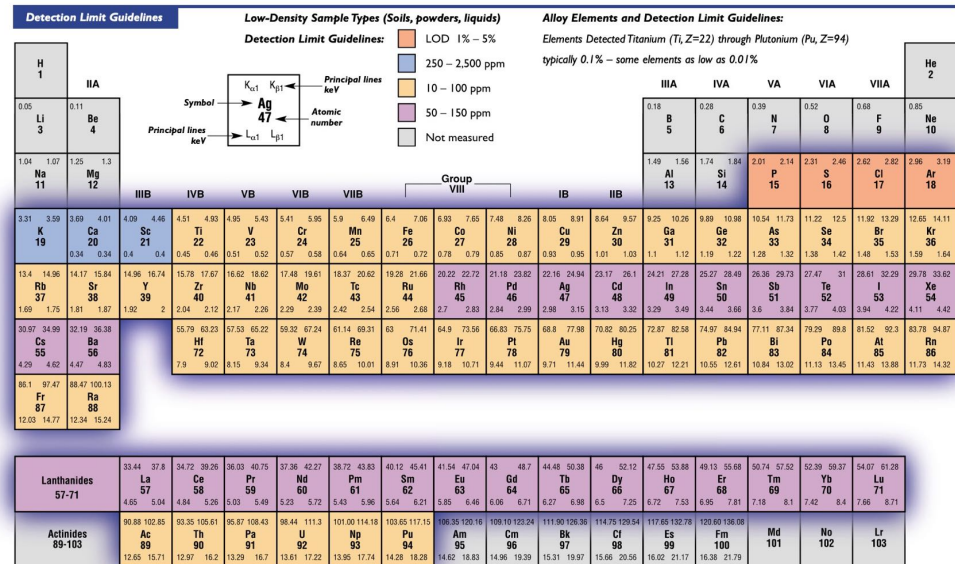
Main emission lines: 583, 2614 keV

Decay chain: Th-232

Related lines: 238, 338, 727, 911, 1588 keV

Excitation Source: W Anode X-Ray Tube
10-40 kv, 50 microamps
Detector: Si PiN Diode
Manufactured in 2007

Featuring X-ray Tube Technology – No Radioactive Isotopes.



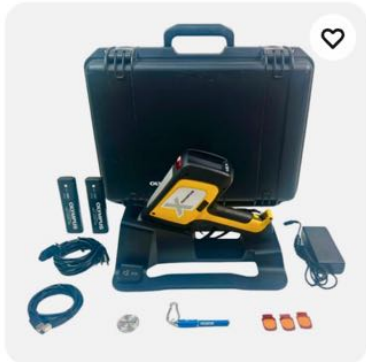
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Refurbished

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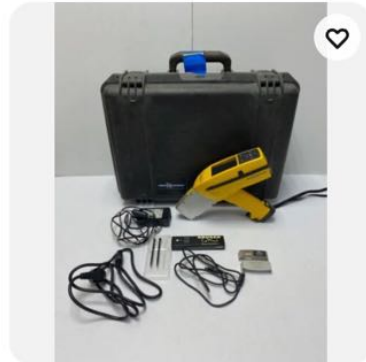
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InnovX systems Olympus XPD-2000 Alloy XRF Analyzer with Accessories

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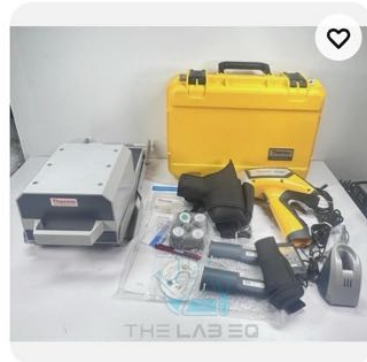
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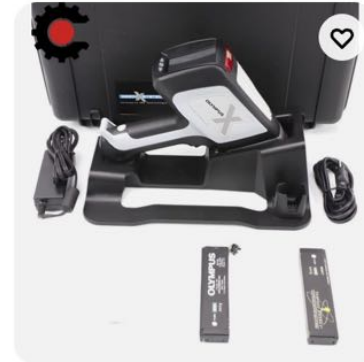
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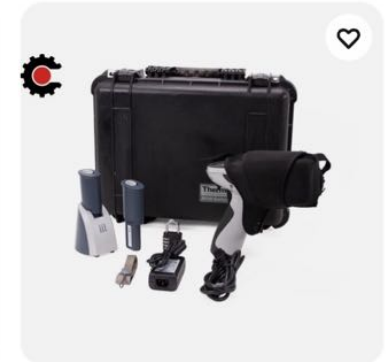
Olympus DELTA DP-2000 Handheld XRF Analyzer w/ Alloy Plus & Window Guard Mode

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LAST ONE

Thermo Scientific Niton XL3t 800 Handheld XRF Analyzer with General Metals

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\$14,999.99

Free delivery

Seller 99.4% positive



Light Elements
In Sample may
Interfere with
analysis

RAYLEIGH (ELASTIC) SCATTERING (CONTINUED)

In addition to Rayleigh scatter peaks at the characteristic lines of the target in the tube, a Bremsstrahlung radiation curve may appear in the background of a spectrum due to Rayleigh and Compton scatter of all incident X-rays (Figure 31).

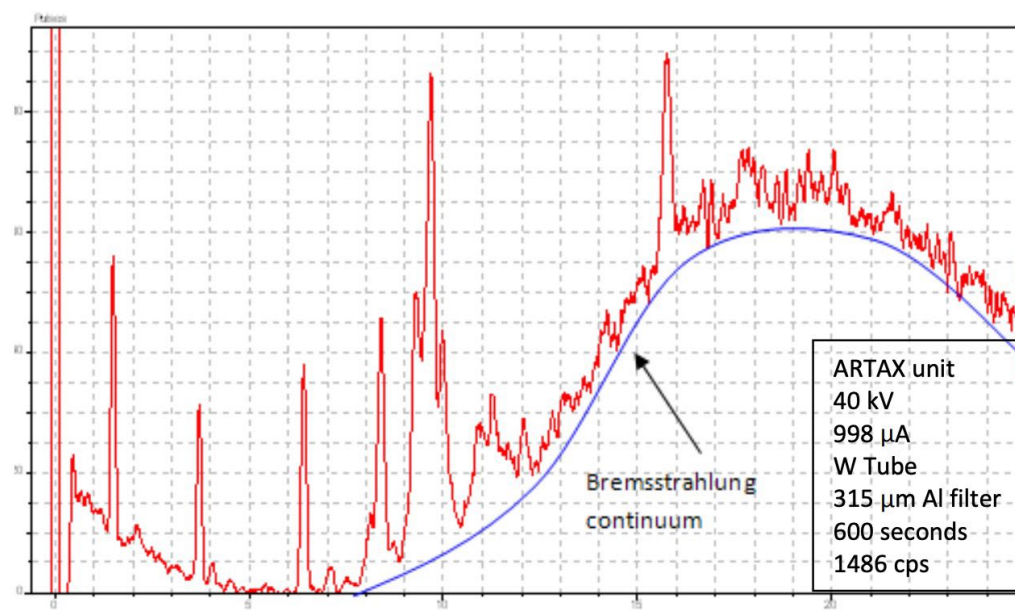
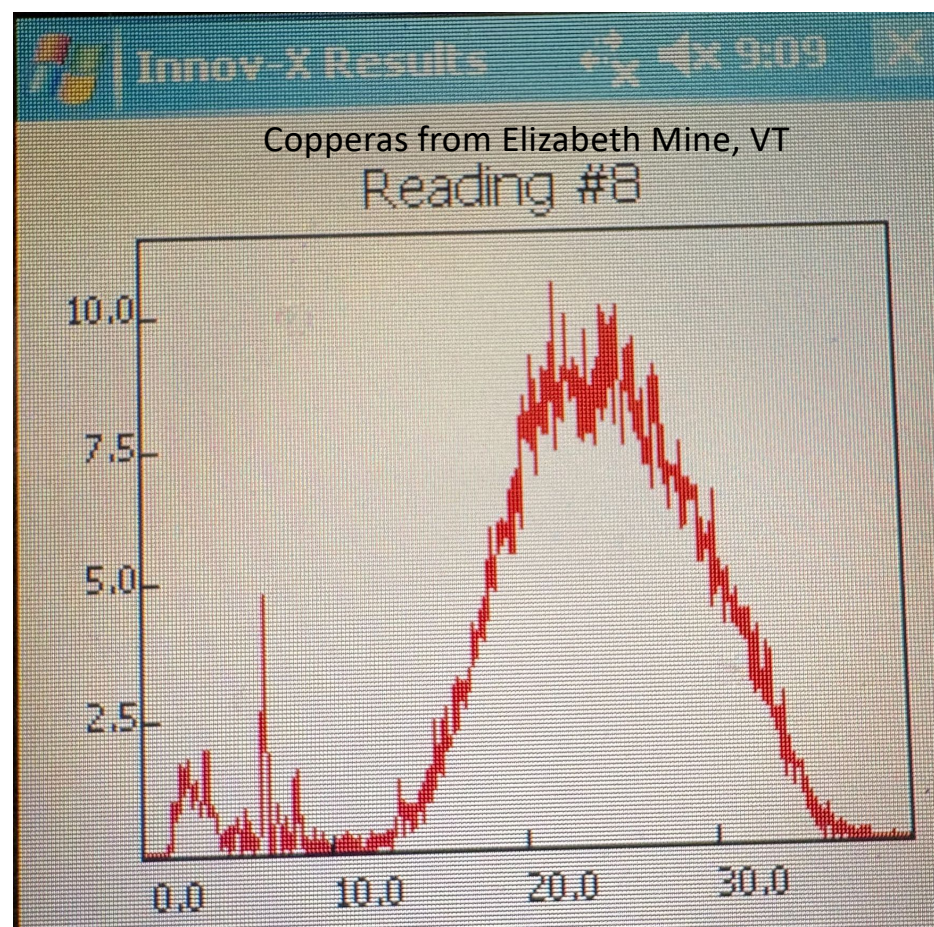
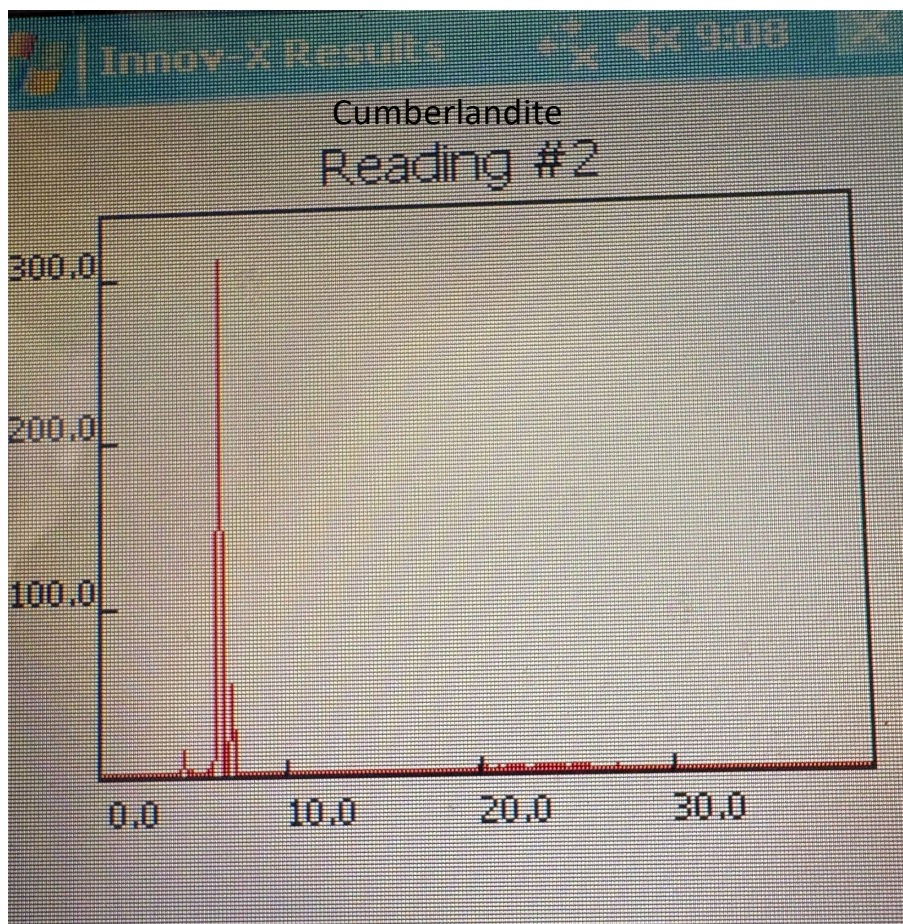


Figure 30: Linear scale spectrum of a high purity Al_2O_3 refractory with a well defined Bremsstrahlung continuum

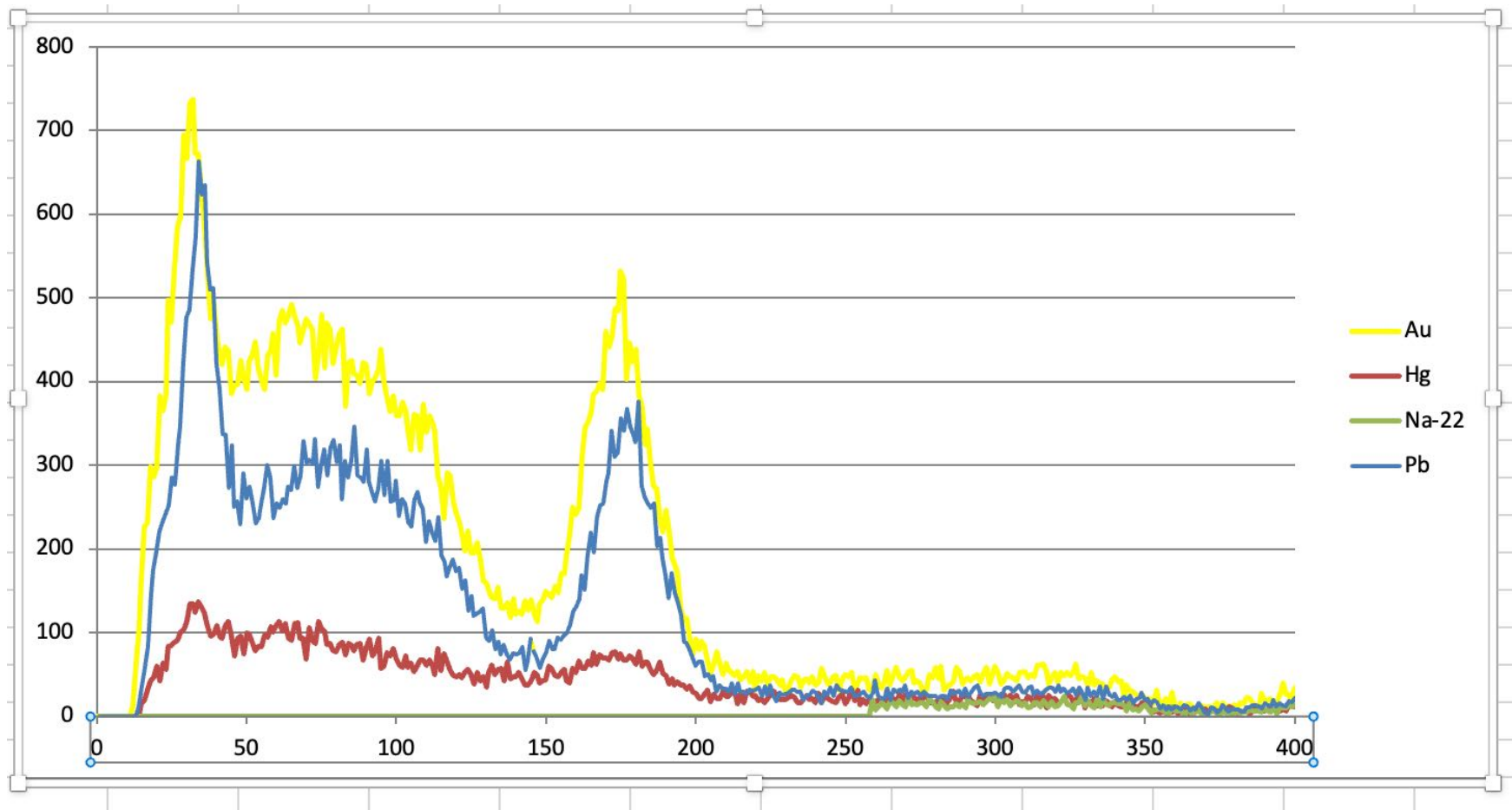
XRF Peaks – Innov-X Alpha 4000



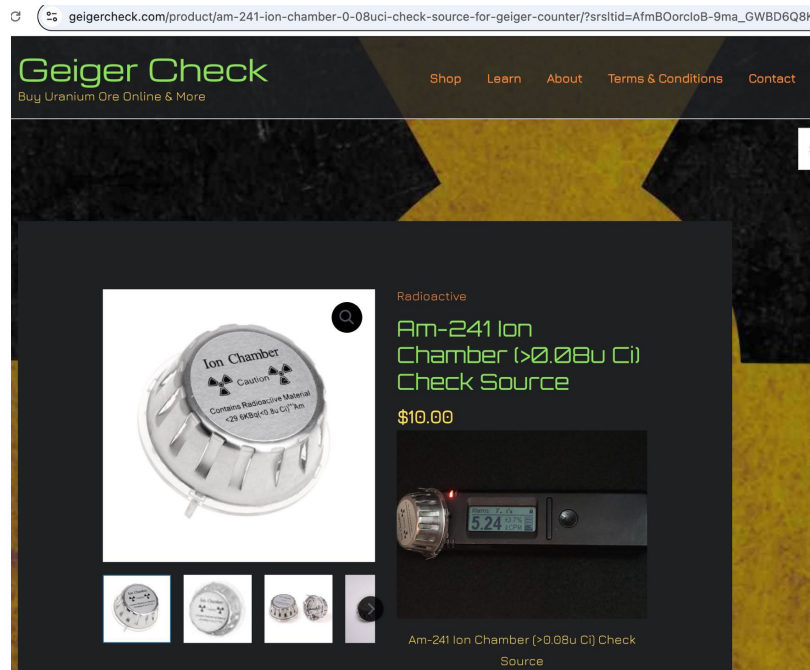
Gamma Ray Analysis
Using Radiacode 102



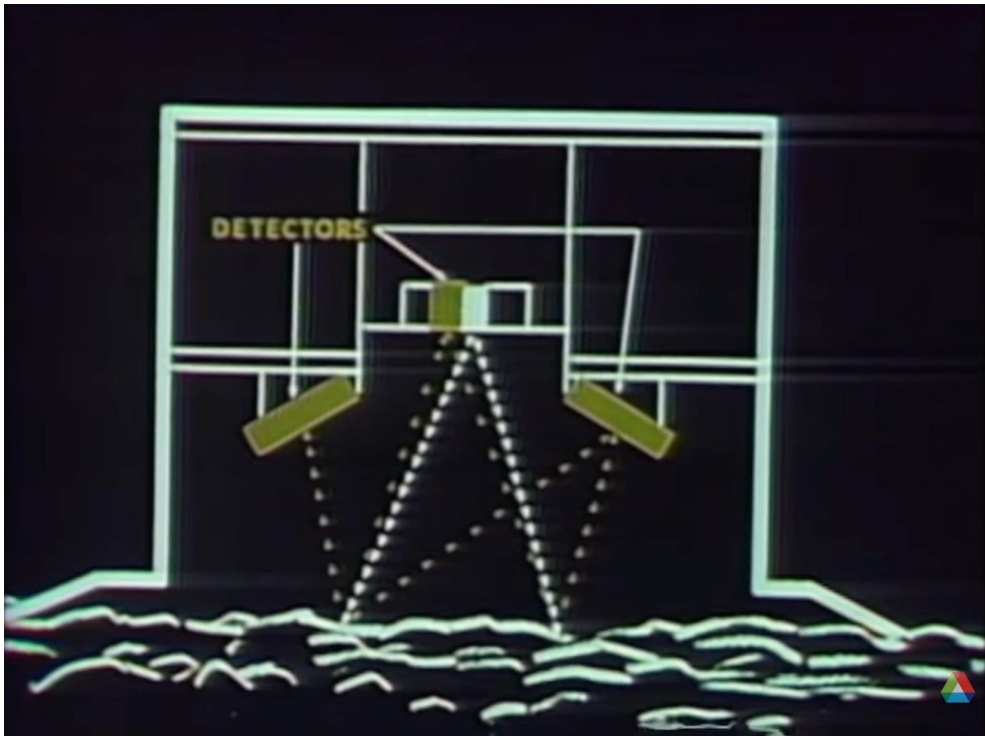
Gamma Ray Analysis Using Radiacode 102



Alpha Scattering Experiments

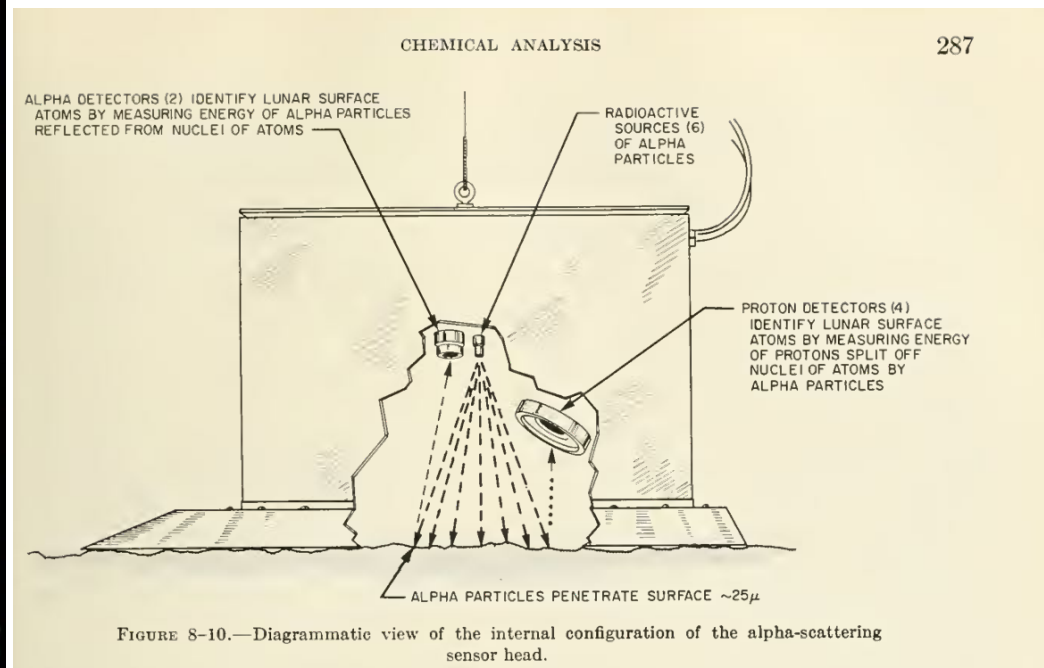


<https://www.radviewdetection.com/alphahound>



Source: Surveyor 5 Launches 9/8/1967(JPL Film)
<https://youtu.be/9K5vRXJOEyQ?si=f5Hv4WPLq0XYFP05>

Surveyor Program Results NASA SP-184



Sources. Curium-242 is used as the source of alpha particles for the analysis. Its half-life, 163 days, is short enough to allow sources to be prepared with the necessary high activity per unit area and narrow energy distributions, yet long enough that the sources have adequate lifetimes. The main energy of the alpha particles from Cm^{242} is 6.115 MeV, with about one-fourth of the particles 44 keV lower in energy. However, because of internal conversion of this energy, the number of 44-keV

(1) The greatest resolution between mass numbers is at a scattering angle of 180° (although there is very little change above 160°).

(2) The resolution decreases rapidly with increasing mass number.

The practical resolution limit for distinguishing individual elements for the instrument used in the Surveyor program is approximately at mass number 40 (Ca).

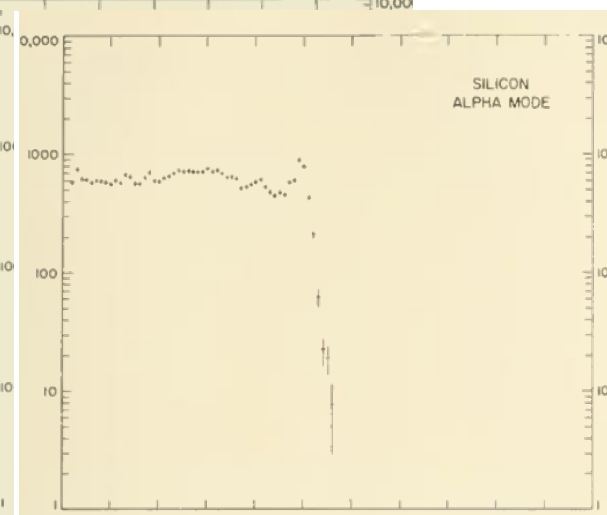
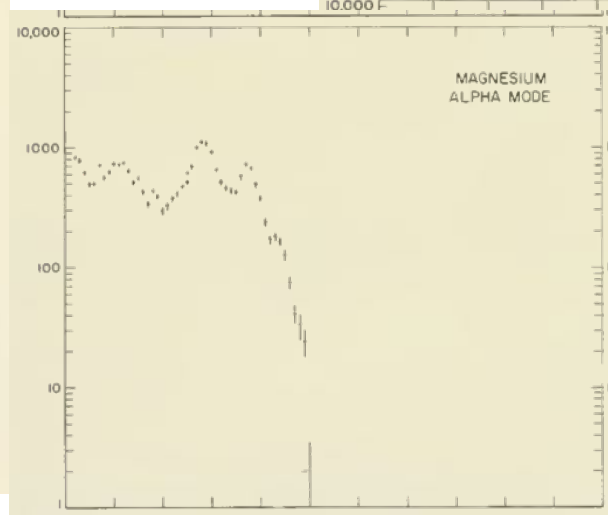
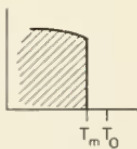
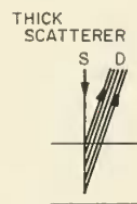
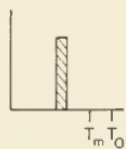
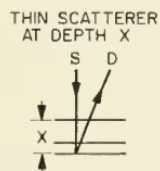
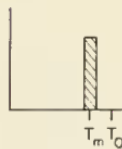
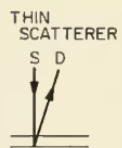
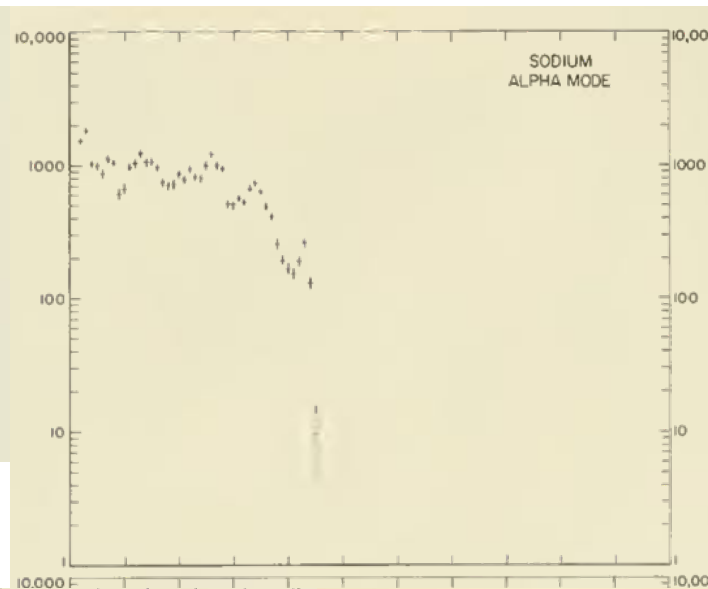
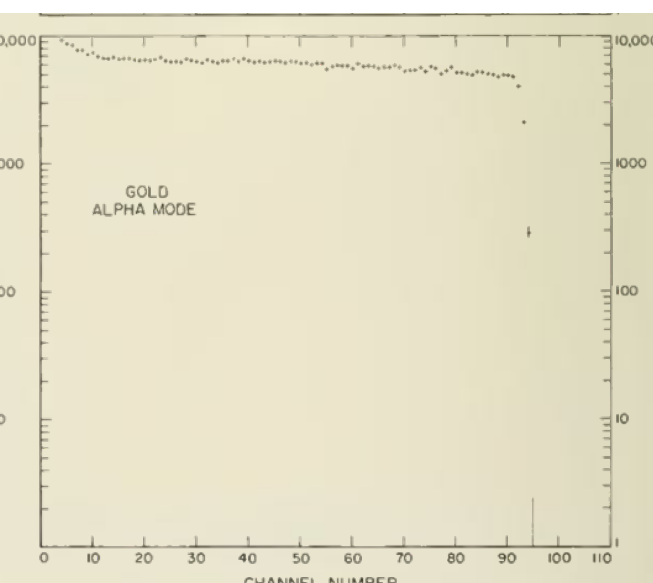
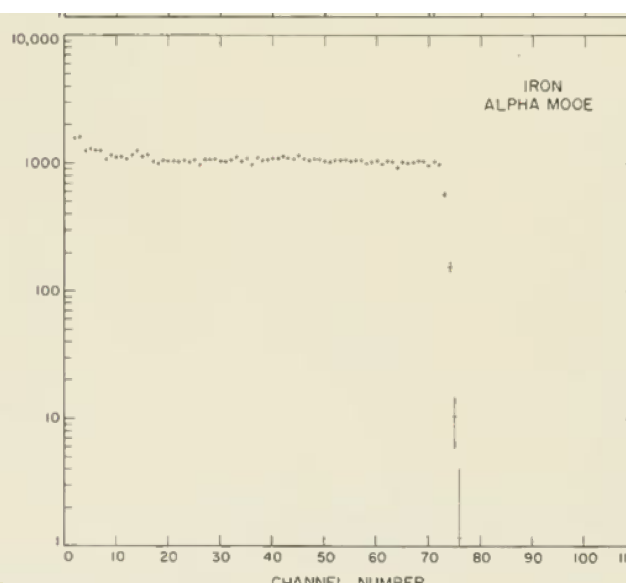
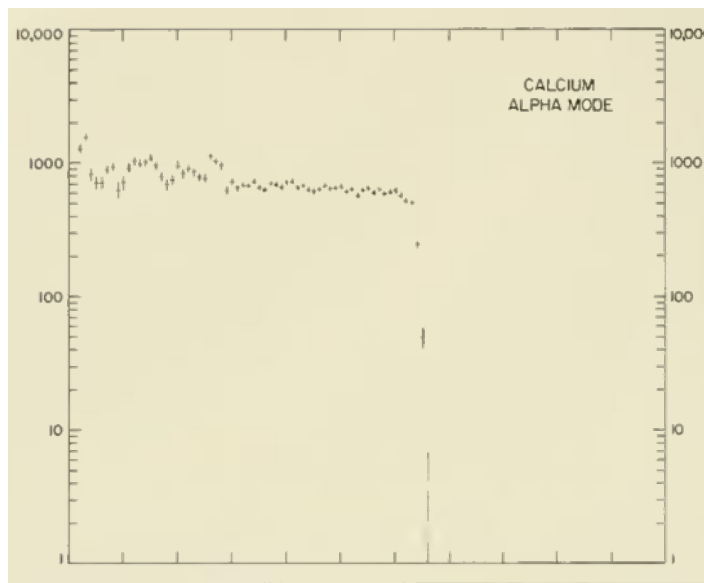


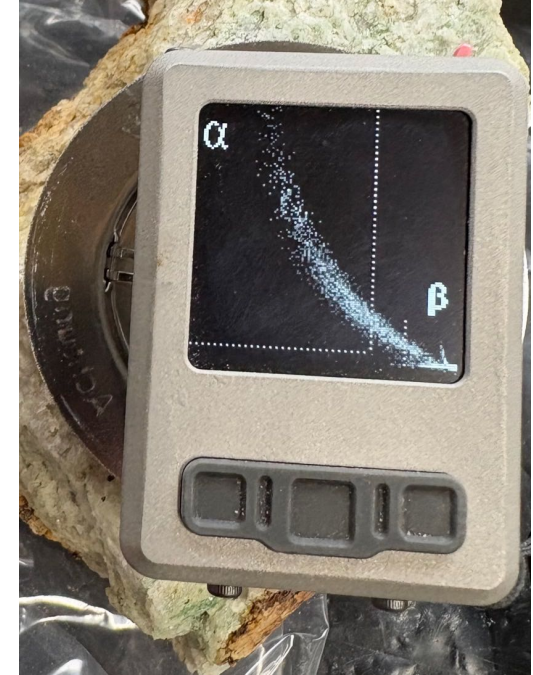
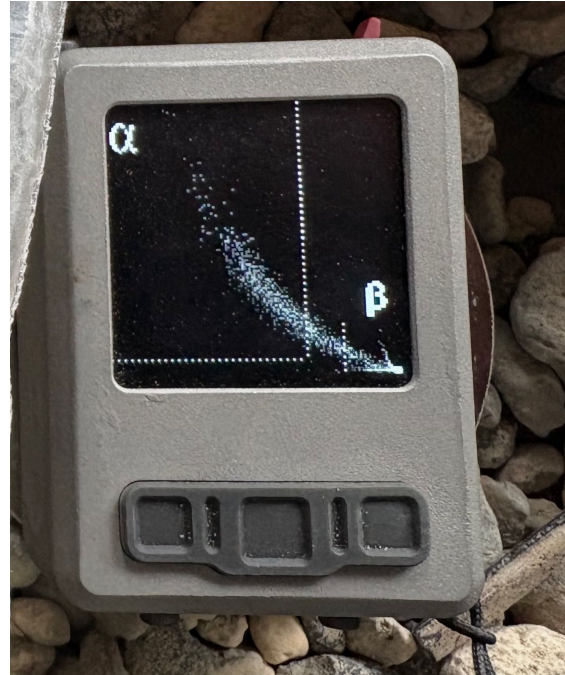
FIGURE 8-2.—Comparison of spectra of alpha particles scattered from thin and thick samples. The upper diagrams show the geometry of scattering; the lower diagrams indicate the corresponding shapes of associated spectra.



Rock element	Dunite	
	Alpha	Conventional ^b
Hydrogen.....		4.3
Carbon.....	(c)	.05
Oxygen.....	58.2 ± 0.5	56.0
Fluorine.....	0 ± 0.0	.01
Sodium.....	0.02 ± 0.06	.01
Magnesium.....	19.4 ± 0.5	23.1
Aluminum.....	0.12 ± 0.07	.19
Silicon.....	15.0 ± 0.6	13.9
Phosphorus.....	0.02 ± 0.06	0
Sulfur.....	2.3 ± 0.5	(d)
Chlorine.....	(c)	.01
"Calcium" ^f	(c)	.1
"Iron" ^f	2.38 ± 0.8	2.32
"Barium" ^f	(c)	(d)

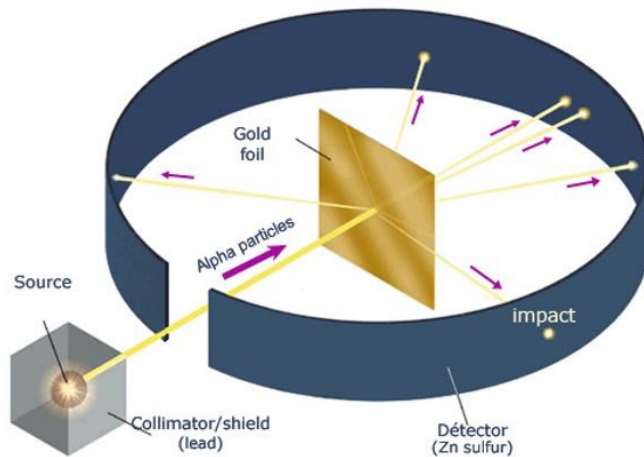
^f "Calcium" represents potassium and calcium; "iron" denotes the elements titanium through zinc, inclusive; "barium" means all the elements heavier than zinc.

TABLE 8-1. Comparison between alpha and conventional analyses of some rocks (in atomic percent)



Backscatter from Phosphate

Backscatter from Copper Ore



https://youtu.be/Qi_EMo9nGOw?si=bdyAqGbLH8l5lg_z

Conducted in 1909–1911 by [Ernest Rutherford](#), Hans Geiger, and Ernest Marsden, the gold foil experiment fired positively charged alpha particles at thin gold foil. It revealed that while most particles passed straight through, some deflected at large angles or bounced back, proving the atom is mostly empty space with a dense, tiny, positively charged nucleus.



Gilding Flakes Set,Gold Foil Flakes for Resin,3 Bottles Metallic Foil Flakes for Resin Jewelry Making,Nails,Painting Art,Crafts and Slime(Gold, Silver, Copper Colors)

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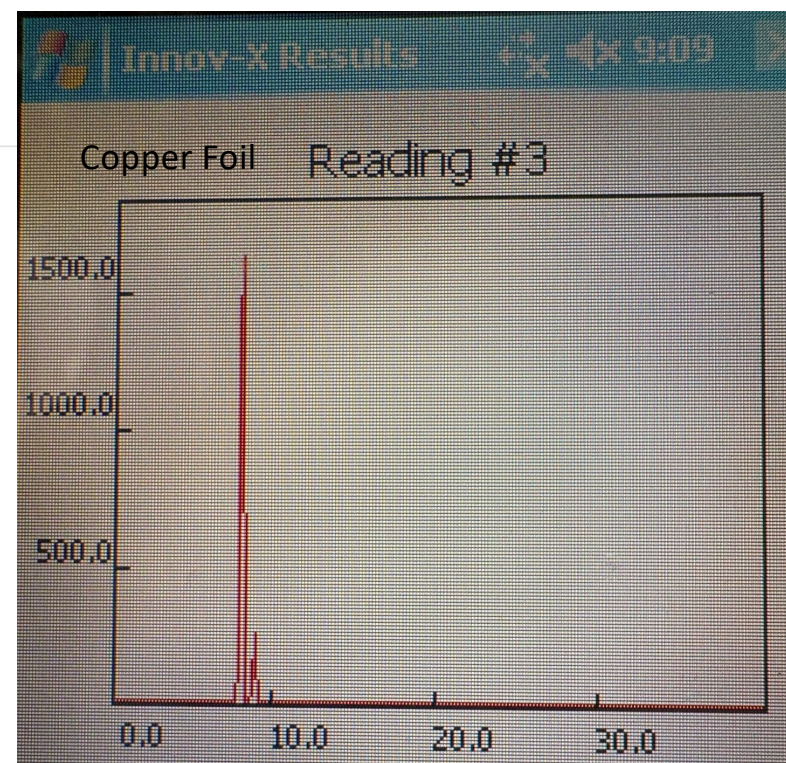
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	Copper Foil		Silver Foil	
	peak	ppm	peak	ppm
Element				
Fe			6.41	28902
Fe			7.02	28902
Cu	8.05	>10%	8.09	2162
?				
Zn			8.64	682
Cu	8.91	>10%		





Edible Gold Leaf Sheets, 1.7 x 1.7 in, Pack of 10 Edible Gold Leaf Sheets for Cakes, Desserts, Candies, Art and Craft, Face Masks and Nail Art (10 Sheets)

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\$12⁹⁹

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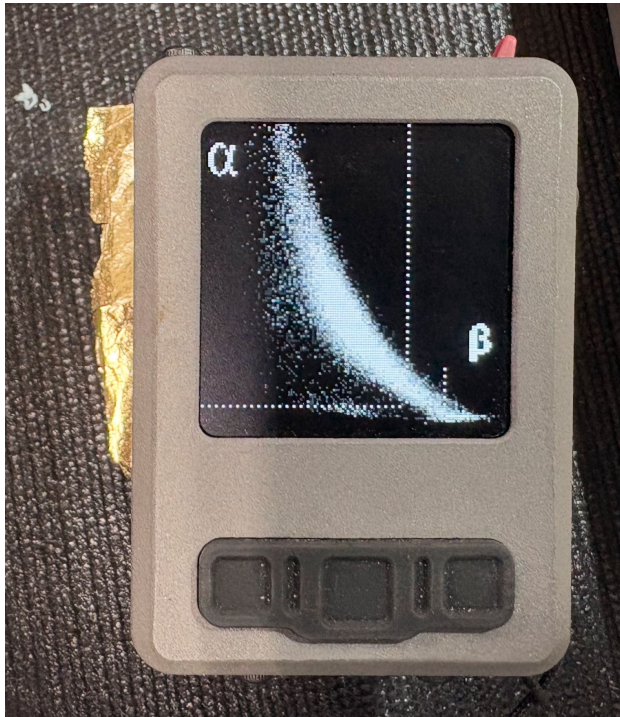
Color: 10 Sheets



Is it pure gold?
Is it “edible”?
If it tastes bad, don’t eat it!

	“Edible Gold Leaf”	Mingjiejus Gold Colored Foil	1 oz Gold Ingot
	Peak	Peak	Peak
Element			
Cu	8.05	8.05	
?			8.46
Zn	8.64	8.64	
Zn	9.55		
Au			9.71
Au			11.44
			13.39

Alpha Penetration Analysis - AlphaHound



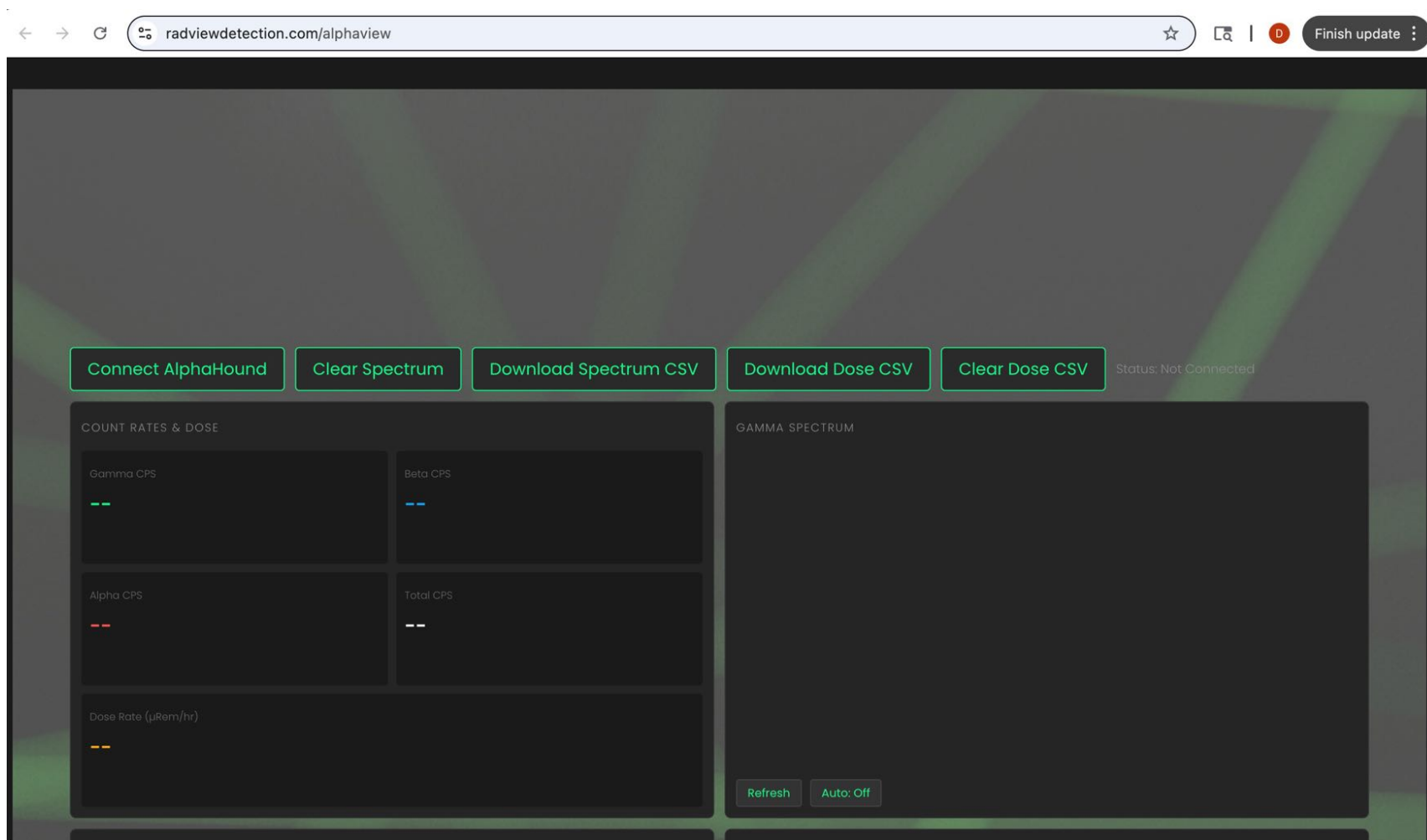
"Edible Gold Leaf"



Silver Foil



Copper Foil



Interface for alpha spectroscopy in beta testing!



ASTROMATERIALS 3D EXPLORER












Sample 10017,15

Collection Apollo Lunar Collection
Origin Moon
Collected LM Site, Mare Tranquillitatis, Apollo 11
Classification High-Ti, High-K Ilmenite Basalt

Micro X-Ray Computed Tomography

Cut into the rock from three different orientations to reveal X-Ray CT imagery of the rock's interior.

Slice Orientation and Position

Use your mouse to drag the sliders below. Release the mouse for full resolution imagery.

X 5.129 cm

Y 5.005 cm

Z 5.445 cm

Details

Make fine selection changes with +- and open high resolution slice imagery.

	View XCT Planes	XCT Slice Number	View Slice	XCT Slice Number	View Slice
X		- 1691 +		- 0000 +	
Y		- 0000 +		- 1650 +	



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↗ 84 ♥

24PCS Geology Microscope Prepared Slides Mineral Thin Section Slides Set

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Condition: **New** ⓘ

Sale ends in: **11h 20m**

Quantity: 6 available · **56 sold**

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Tips to Avoid Damage to slide and objective lens

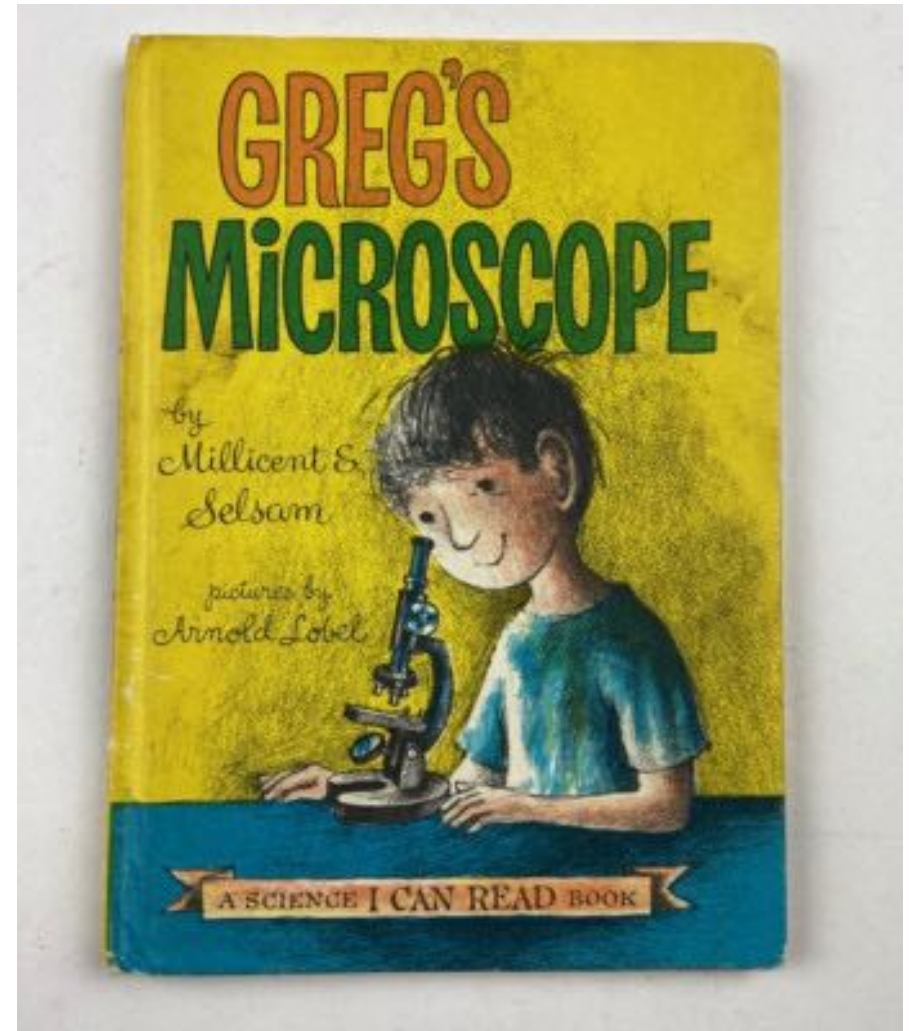
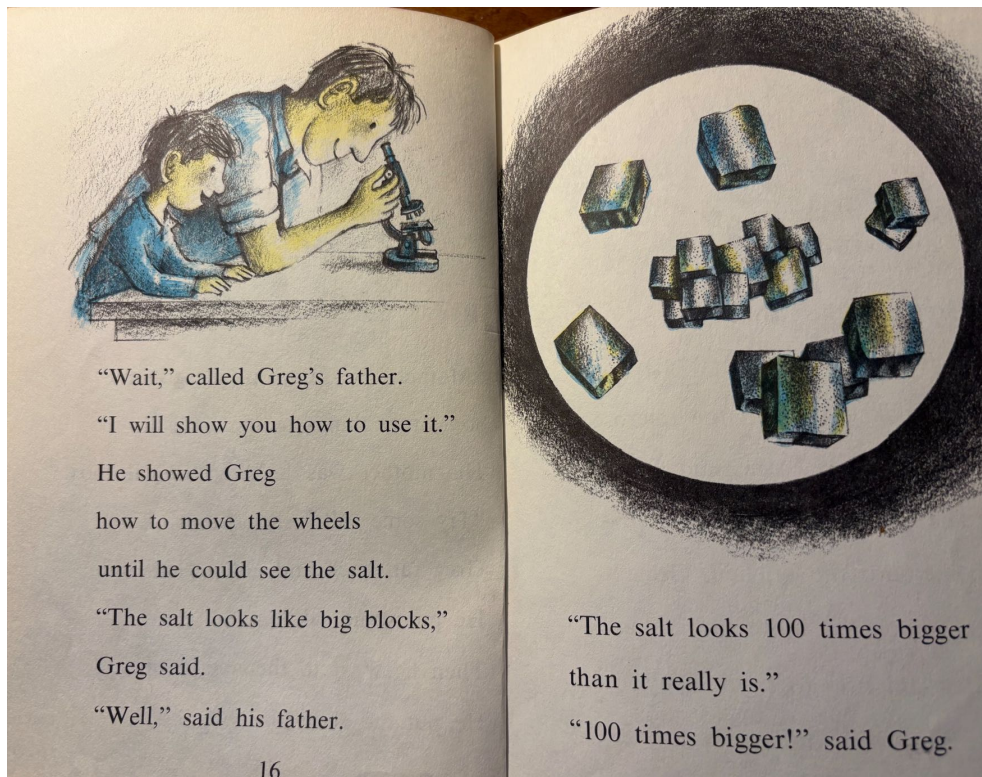
Work on cloth or mat

Secure eyepiece to tube with tape

Use low power objective lens first

Look at microscope from side before adjusting focus

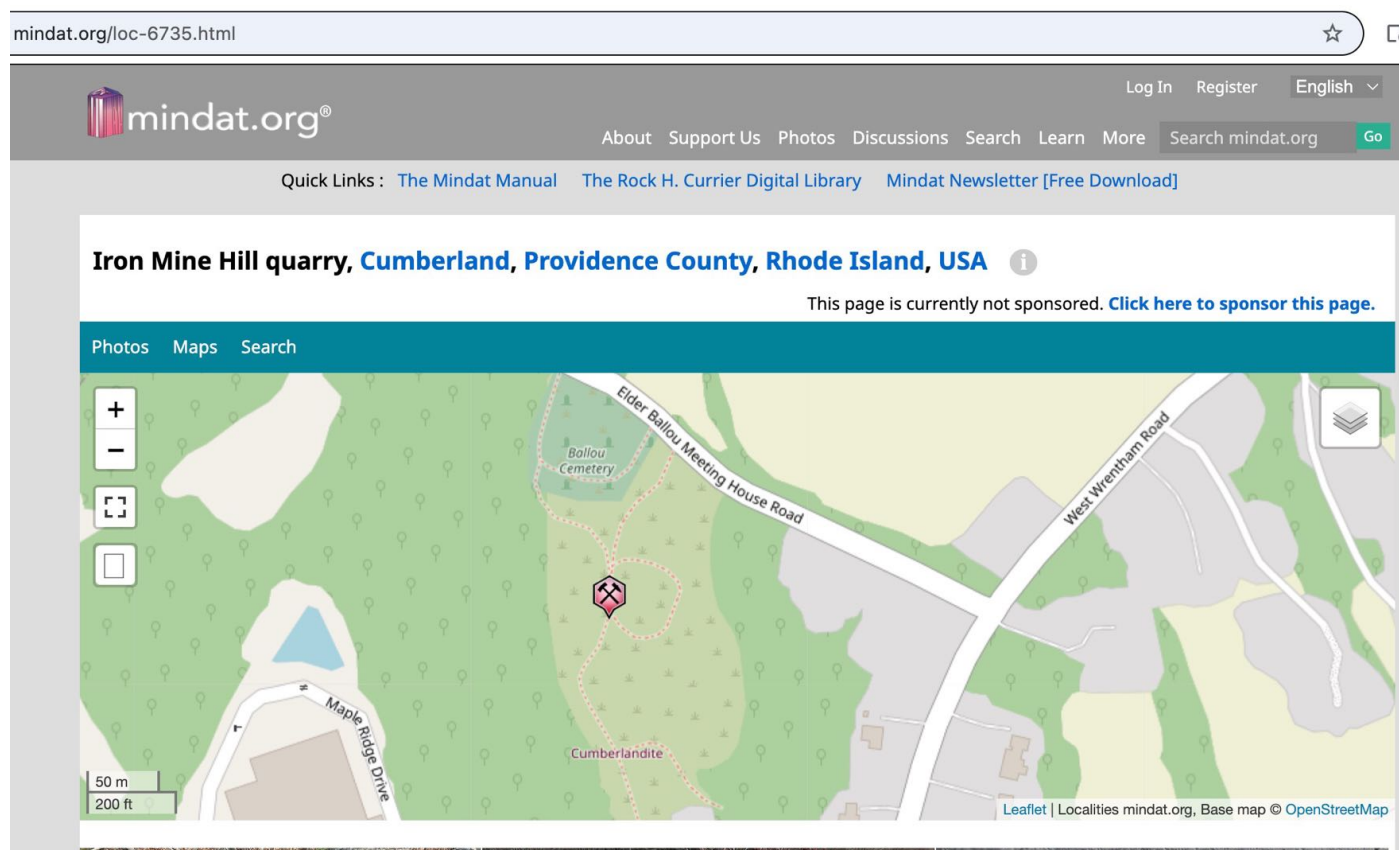
Don't rub dirty lenses

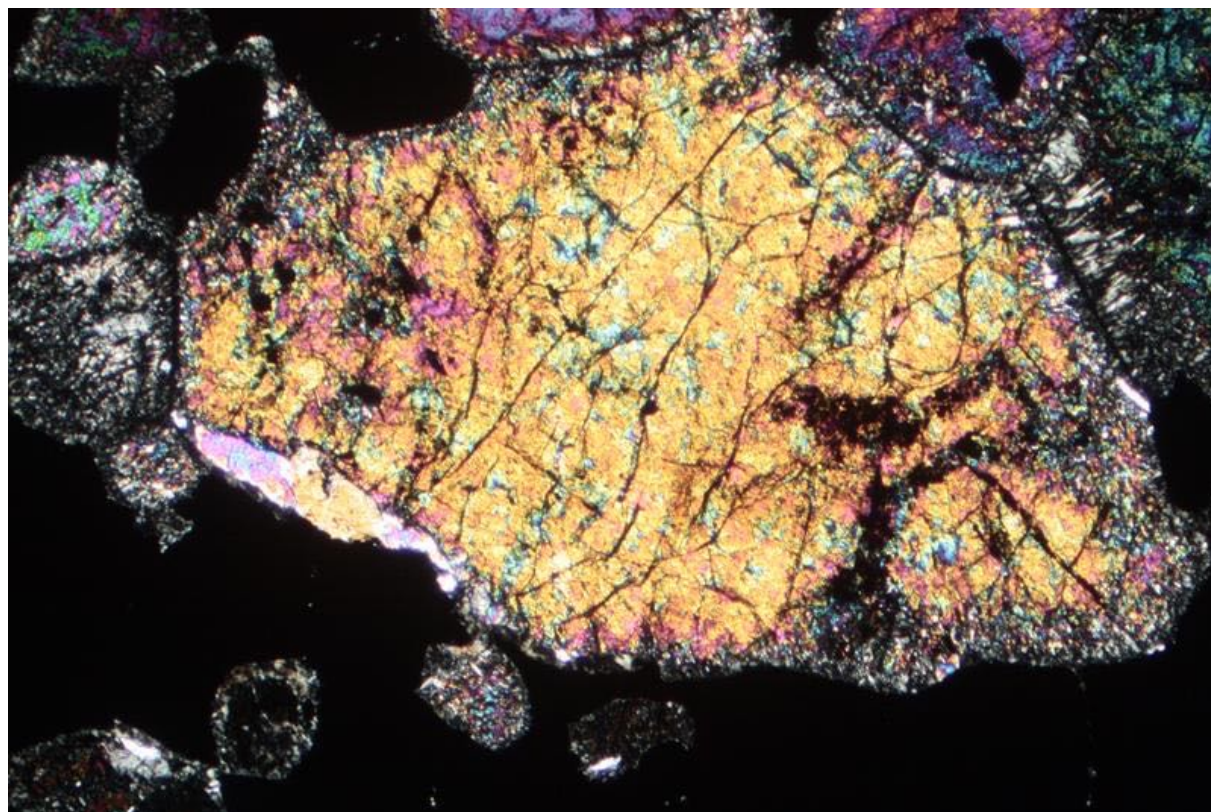
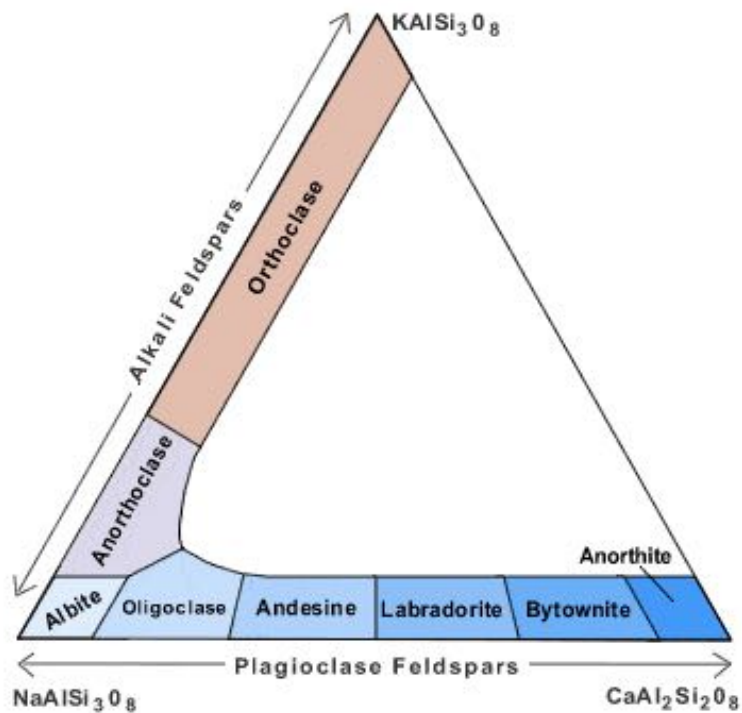


Cumberlandite (titaniferous magnetite melatroctolite).

Troctolite: a mafic, coarse-grained intrusive igneous rock, often called "trout rock" (*forellenstein*) for its spotted appearance. Composed mainly of olivine and calcic plagioclase, it is a pyroxene-depleted type of gabbro.

Intruded into the Late Proterozoic Blackstone Group between 620 and 370 mya. Formed by gravitational settling of olivine, titaniferous magnetite and cumulophyric plagioclase-olivine aggregates from an anorthositic gabbro magma. <5% pyroxene





Olivine (brown) and magnetite-ilmenite crystals. Cumberland, Rhode Island, USA. XPL image, 2x (Field of view = 7mm)
<https://www.alexstrekeisen.it/english/pluto/cumberlandite.php>



Genuine Rare MOON DUST From Lunar Meteorite Adrar 013 - A Unique Gift Idea!

the.interstellar.collection (528)
100% positive · Seller's other items · Message seller

US \$48.99

Condition: New

Quantity: 1 Out of Stock · 31 sold

Shipping, returns, and payments

Shipping: US \$8.00 USPS Priority Mail®. See details
Located in: Huntingdon Valley, Pennsylvania, United States
Delivery: Estimated between Sat, Apr 18 and Fri, Apr 24 to 02664

XRF			
Element	ppm	peak	peak
Ti	3971	4.5	
V?	2139		
Cr?	1822		
Mn?	1210		
Fe	8283	6.35	7.04
Co?	340		
Ni?	315		
Cu?	100		
Zn?	72		
As?	555		
Pb?	43		
Ca		3.72	
Os/Ir?		10.46	

LPI

HomeAbout

This is 1 of 60 approved meteorites classified as Lunar (melt breccia).
Search for other: Lunar meteorites

Comments:

Approved 14 Feb 2024

Writeup

Writeup from MB 113:

Adrar 013

27°07'48.70"N, 01°02'01.43"E

Adrar, Algeria

Purchased: 2023

Classification: Lunar meteorite (melt breccia)

History:

The meteorite was purchased from a meteorite dealer in Timokten, Algeria.

Physical characteristics:

Several grayish-greenish fragments including a large 3 kg single stone.

Petrography:

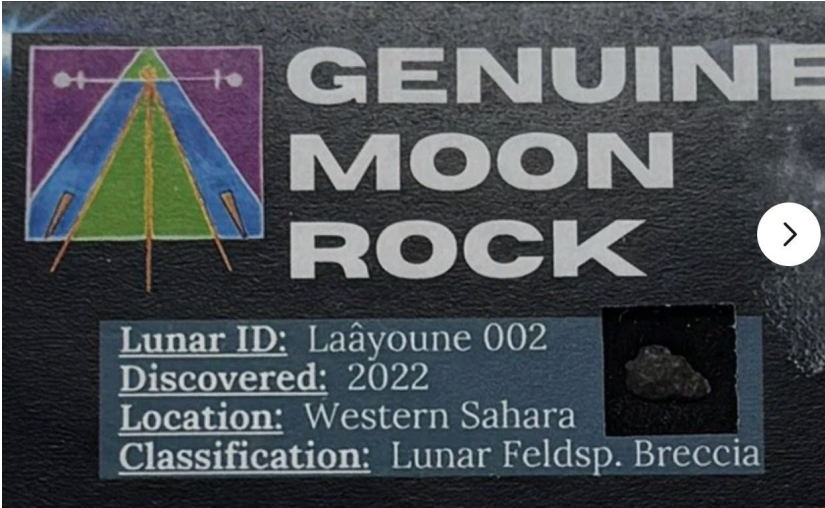
Melt breccia composed of grayish-greenish clasts set in abundant anorthite-rich melt rock matrix displaying pronounced flow and quench textures with small anicular crystals nucleating on larger entrained mineral grains. Major phases are pigeonite, often zoned augite and less abundant olivine. Minor phases include ilmenite, chromite, and troilite.

Geochemistry:

olivine: $\text{Fa}_{24.0\pm0.1}$ ($\text{Fa}_{23.9-24.2}$, $\text{FeO}/\text{MnO}=84\pm8$, $n=7$); pigeonite: $\text{Fs}_{25.0\pm1.3}\text{Wo}_{10.0\pm0.5}$ ($\text{Fs}_{21.9-27.1}\text{Wo}_{9.1-10.6}$, $\text{FeO}/\text{MnO}=47\pm3$, $n=7$); zoned Ca-pyroxene: $\text{Fs}_{23.4\pm3.2}\text{Wo}_{29.3\pm6.2}$ ($\text{Fs}_{20.4-26.4}\text{Wo}_{16.1-35.2}$, $\text{FeO}/\text{MnO}=45\pm5$, $n=7$); calcic plagioclase: $\text{An}_{95.8\pm0.8}$ ($\text{An}_{94.8-97.7}$, $n=7$)

Classification:

Melt breccia (anorthositic norite/gabbro) based on Stoeffler et al. (1980).





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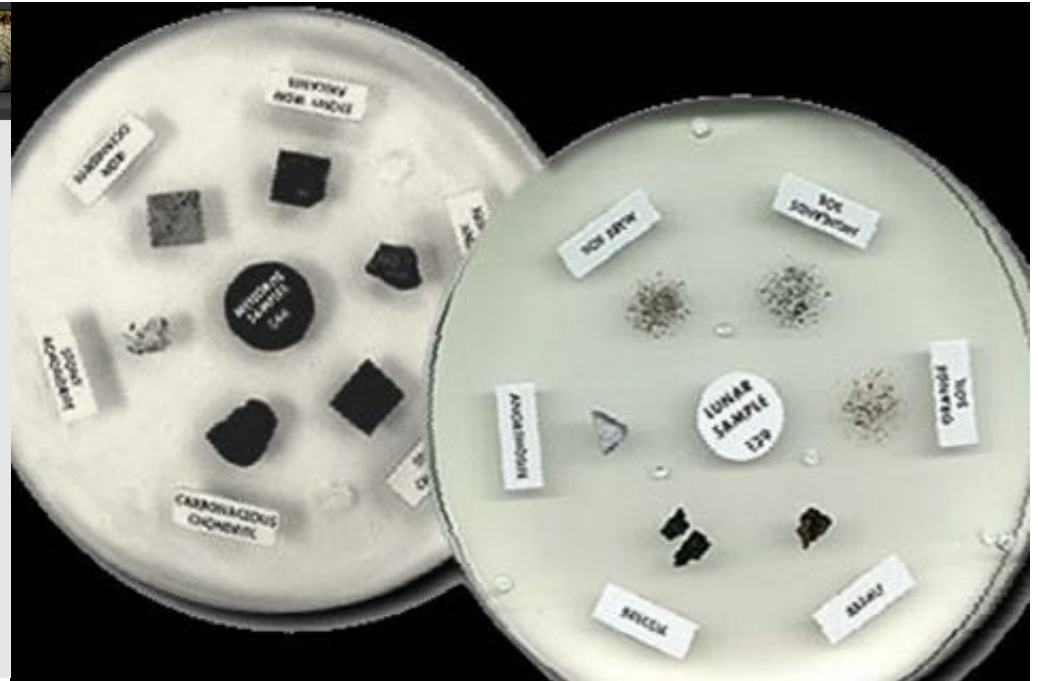
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► NASA's Earth's Moon Website

LUNAR PETROGRAPHIC THIN SECTION SET

Each Package includes a lunar thin section set consisting of 12 polished sections of rocks and soils, specifically selected to represent the lunar collection. The samples represented in this set are listed on the table below. Click on the sample number to see a description of the sample from the [Lunar Petrographic Thin Section Set Study Guide](#), written by Dr. Charles Meyer along with photos and links to associated resources and references.

Sample Number	Mission	Rock Classification
12002	Apollo 12	Mare Basalt
12005	Apollo 12	Mare Basalt
77017	Apollo 17	Mare Basalt
74220	Apollo 17	Mare Basalt
60025	Apollo 16	Plutonic
78235	Apollo 17	Plutonic
14305	Apollo 14	Breccia
65015	Apollo 16	Breccia
72275	Apollo 17	Breccia
68501	Apollo 16	Lunar Regolith
70181	Apollo 17	Lunar Regolith
15299	Apollo 15	Lunar Regolith



Borrowing Process:

Teachers must first complete the Lunar and Meteorite Certification Workshop. Requests must be submitted at least six weeks in advance, and a strict, secure storage plan (e.g., in a safe or bank) is required.

<https://ares.jsc.nasa.gov/interaction/lmdp/borrow.html>

Astromaterials Research & Exploration Science

LUNAR & METEORITE SAMPLE DISK PROGRAM (K-12)



ARES CURATION RESEARCH MISSIONS SAFETY IMAGE SCIENCE ENGAGEMENT PEOPLE

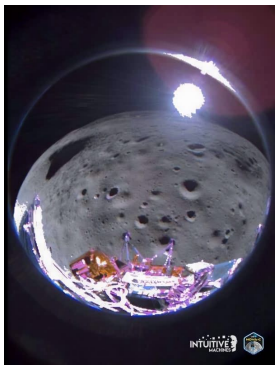
The Lunar and Meteorite Sample Disk Program is intended for full-time K-12 classroom teachers. To be eligible to receive the Sample Disks, a user must be employed (receiving a paycheck) by a qualified learning institution. Educators must be certified to borrow the Lunar and Meteorite Sample Disks by attending a [NASA Certification Workshop](#) provided by a NASA Authorized Sample Disk Certifier.

For further information or questions, please contact [Bridget McInturff](#)

daniella.velasquez@nasa.gov

Each Lunar and Meteorite Sample Disk encapsulates six authentic Astromaterials samples in a six-inch diameter clear Lucite disk. Each Meteorite Sample Disk contains six different types of Meteorite samples. Each Lunar Sample Disk contains three Lunar rock and three Lunar soil (regolith) samples collected by Apollo astronauts.

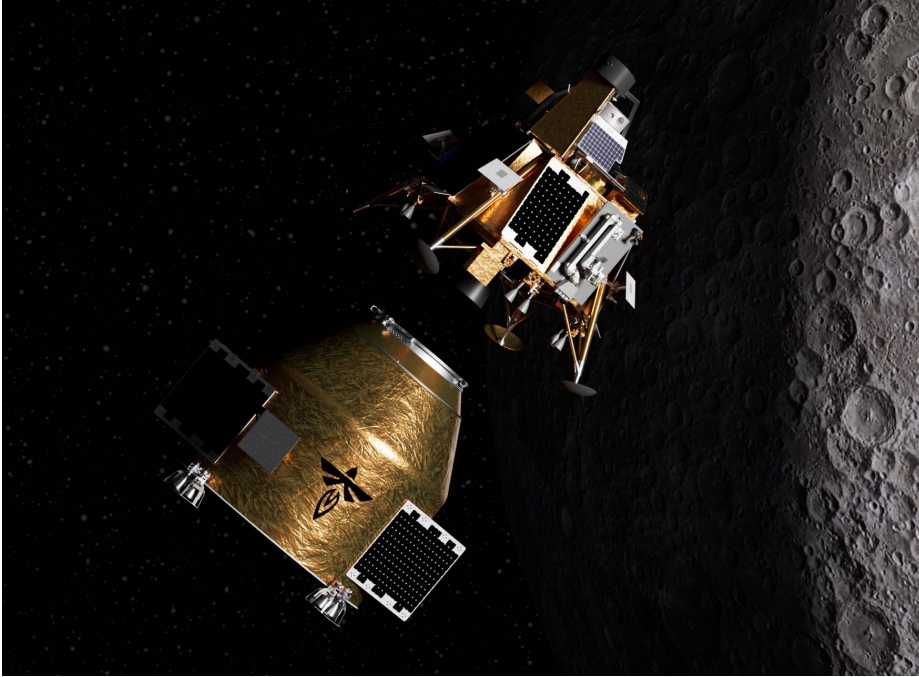
Intuitive Machines' IM-1 mission successfully landed its *Odysseus* lander near the Moon's South Pole on February 22, 2024, becoming the first commercial entity to achieve a lunar soft landing and the first U.S. landing in over 50 years. Despite tipping over upon landing, it successfully transmitted data before losing power on March 23, 2024.



Intuitive Machines' [Athena](#) lunar lander (IM-2 mission) successfully touched down near the Moon's south pole (Mons Mouton) on March 6, 2025, but tipped onto its side, causing a premature mission end. Despite reaching the surface, the "wonky" landing prevented proper solar power generation, and the lander was declared dead on March 7, 2025.



The initial IM-1 contract was valued at \$77 million but increased to \$118 million through modifications. The \$118 million covered transport of NASA experiments, with the agency spending an additional \$11 million to develop those instruments.



Firefly Aerospace's **Blue Ghost Mission 1** successfully landed on the Moon on March 2, 2025, becoming the first fully successful commercial lunar landing, operating in the Mare Crisium basin. It delivered 10 NASA science instruments and operated for over 14 days, capturing crucial data and images of a lunar eclipse.



Blue Ghost was launched from Kennedy Space Center using a SpaceX Falcon 9 Block 5 rocket that delivered 10 payloads to Mare Crisium. Its 60-day mission aimed to analyze lunar regolith, study geophysical characteristics, and investigate interactions between the solar wind and Earth's magnetic field. The lander's scientific payloads included a regolith adherence characterization experiment, a lunar retroreflector for precision distance measurements, a radiation-tolerant computer, thermal exploration probes, and more.

NASA's Artemis Program (Moon to Mars)

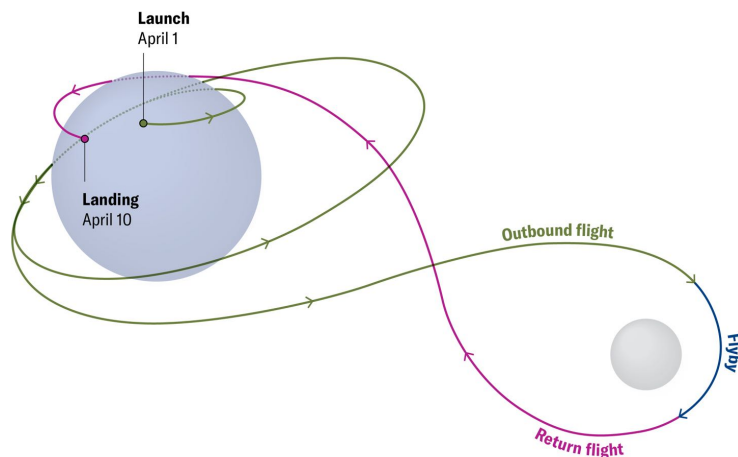
- Purpose:** Establish a long-term human presence on the Moon, test technologies for future Mars missions, and foster commercial partnerships.

- Artemis I (2022):** Uncrewed test flight of the Space Launch System (SLS) rocket and Orion spacecraft.

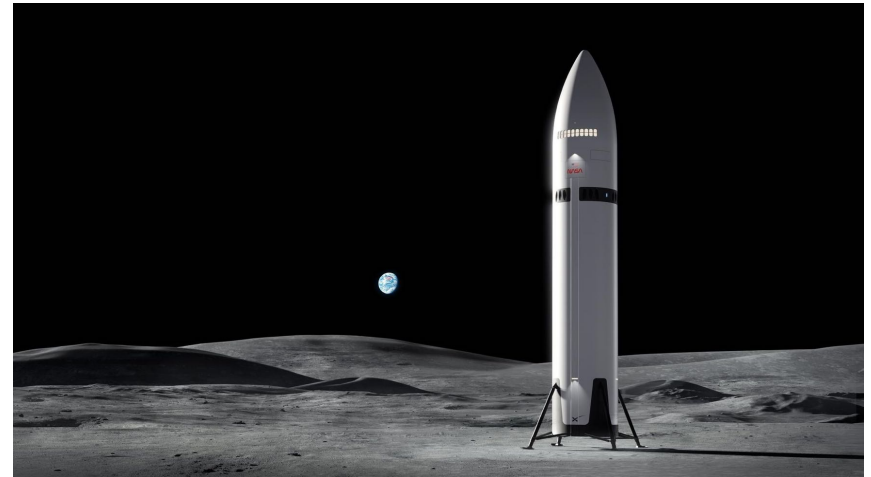
- Artemis II (April 2026):** Crewed 10-day mission around the Moon and back, marking the first human moon mission in over 50 years.

- Artemis III/IV (2027-2028):** Planned crewed lunar landings, with a focus on landing astronauts near the lunar South Pole.

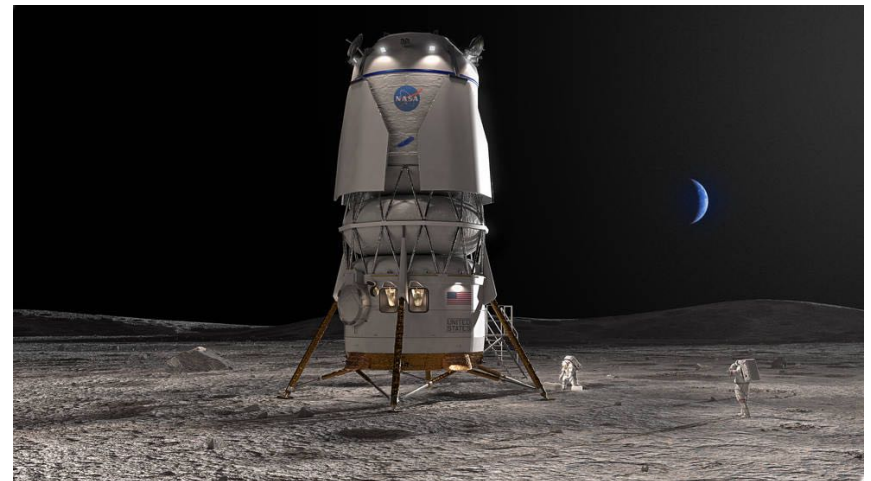
Artemis II Flight Path



<https://www.nasa.gov/reference/human-landing-systems/>



SpaceX's Starship Human Landing System



Artist's concept of the Blue Moon lander. Blue Origin